

विज्ञान की तैयारी

A Preparation for Science

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प्रस्तावना

यह किताब विज्ञान नहीं सिखाती है, लेकिन वैज्ञानिक वृत्ति—विज्ञानशास्त्री के स्वभाव—का अनुशीलन कराके विज्ञान की तैयारी कराती है। किताब बहुत छोटी है। छठे परिच्छेद में जो ३१ पाठ हैं, वही असली किताब है; और कम से कम साधनों की मदद से देहात के बालकों को निरीक्षण, परीक्षण और प्रयोग के द्वारा कुदरत को हम कैसे पहचानें और अपने मन और जीवन को कैसे उन्नत करें उसका रास्ता दिखाती है। हरतरह की शिक्षा का मूलधन तो जिज्ञासा या कुतूहल ही है। लेकिन जैसे तलवार को हम तेज करते हैं, उसी तरह इस स्वाभाविक कुतूहल को तेज करना जरूरी है। कोई भी प्रामाणिक, समझदार और मेहनती अध्यापक इस किताब की मदद से यह काम कर सकता है।

यह किताब है तो छोटी, लेकिन इसका संकल्प बहुत बड़ा है। यूरोप के पश्चिमी हिस्से और उत्तर अमेरिका को छोड़ कर बाकी की सारी दुनिया ग्राम-वासियों की ही है, विज्ञान से अनभिज्ञ है। इसी कारण उसका सत्त्व हमेशा चूसा जाता है। ग्रेग साहब को यह बात बहुत खटकती है। वह जानते हैं कि अगर दुनिया का उद्धार होने को है, तो इतनी विशाल दुनिया के देहातों में रहनेवाले लोगों को जागृत करना चाहिए। भविष्य की ओर नजर फेंक कर ग्रेग साहब कहते हैं कि दुनिया के कम से कम पाँचे भाग के लोगों के नेता निकटवर्ती भविष्य में देहात में से ही पैदा होनेवाले हैं। इसीलिए देहाती शिक्षा का और शिक्षकों का विचार हमें गंभीरतया करना चाहिए।

इस किताब के अंत में, विज्ञान के तरफ हमारी कैसी दृष्टि रहे, विज्ञान क्या चीज है, उसकी मर्यादा क्या है, भारतीय संस्कृति पर विज्ञान का क्या असर होगा, इत्यादि महत्व के सवालों की मीमांसा है। ग्रेग साहब पश्चिम के एवं भारत के सर्वोच्च विचारकों के अभिप्राय से सुपरिचित हैं। उन्होंने अनुभव भी अनेकानेक क्षेत्रों में किया है। यूरोप-अमेरिका का रास्ता दुनिया को कहाँ ले जाता है सो भी उन्होंने देखा है। उसे सुधारने में भारतवर्ष का हिस्सा कौनसा हो सकता है, सो भी जानते हैं। उसके लिए भारतवर्ष को तैयार होना चाहिए यह भी वह असंदिग्ध शब्दों में कहते हैं।

आजतक भारतवर्ष ने पाश्चात्य निंदकों का ठीकठीक अनुभव किया है। उसके बाद कई स्तुतिपाठकों का भी भारतवर्ष को परिचय मिला। ग्रेग साहब इन दोनों श्रेणी से विभिन्न हैं। वह भारतवर्ष के सच्चे मित्र हैं, भारतवर्ष पर श्रद्धा रखनेवाले हैं। थोड़े ही दिनों में उन्होंने भारतवर्ष की कीमती सेवा की है। विज्ञान की आधुनिक खोज के अनुसार खादी-प्रवृत्ति कितनी सचोट है, यह बात उन्होंने 'खदर के संपत्तिशास्त्र' में सिद्ध की है।

देहात के अध्यापकगण अंग्रेजी कैसे जानें ? जानने की उन्हें जरूरत भी नहीं है। तो भी विद्यापीठ ने इस किताब को मूल अंग्रेजी में प्रकाशित करना पसंद किया—इस आशा से कि हर एक प्रांत के प्रजाहितैषी शिक्षा-शास्त्री अपनी-अपनी भाषा में इस किताब की शैली पर स्वतंत्र ग्रंथ लिखें। मामूली अनुवाद से काम नहीं चलेगा। देहात के अध्यापकों की भूमिका को ध्यान में रखकर स्थानीय बातों नवीन रूप में और आवश्यक परिवर्तन और परिवर्द्धन के साथ लिखना होगा।

दत्तात्रेय बालकृष्ण कालेलकर

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Introduction

In India and indeed all of Asia the vast majority of the people live in villages and country districts. This is true also in Russia, Africa, South and Central America. Hence, the villages and rural areas will produce the leaders of the next generation of at least three quarters of the peoples of the world. Even in the highly urbanized countries of Western Europe and the United States a very large proportion of the leaders and great men in all realms of activity come from the country, villages, or small towns.

This means, then, that village teachers are an exceedingly important group of people. They have the opportunity to stimulate and mould the intellectual and moral lives of the coming leaders of the world to an extent that is little realized. They will have a very great influence on the amount and direction of future human progress. And in the present situation of the world we are all faced with problems of immense size, complexity, and importance.

One of the most widespread and important series of events now and during the last two hundred years is the close contact and conflict of European culture (which includes that of most of North America) with the cultures of Asia, Africa and South America. It has involved vast suffering. It is part of an immense change. Yet in the past history of the world there have been many instances of fruitful blendings of prior cultures and civilizations arising from such contacts. It is the hope of the world that new and finer cultures, civilizations and nations will arise out of the present welter of conflict. In order that this may come about there must be selection, assimilation and utilization of elements that can be harmonized, and rejection of those which cannot. Much of this selection will be unconscious; some may be conscious.

The confusion, bewilderment, mistakes, waste and tragedies of these cultural conflicts are perhaps most in evidence and most distressing in the economic and social life of the countries where the conflict is occurring, especially Asia and Africa. But they are also painfully evident in their schools, colleges and universities. And because, in the realm of education, so much is self-conscious, it is possible that teachers have a better opportunity than almost any other group in the community to make a *conscious* choice of such parts of Western culture as may be wisely and fruitfully

combined with and assimilated into Eastern modes of thought and life. Certainly the pupils of these teachers will have much to do in the matter. As A. N. Whitehead remarks, "*A clash of doctrines is not a disaster—it is an opportunity."

But the teachers, in India at any rate, are handicapped by their previous training and by lack of time and money to do the reading and thinking which is partly needed as a basis for judgment in such matters. Yet if they will be true to themselves and to their Indian heritage, they will be guided somewhat by their intuitions, and in certain parts of the problem that will be the best and surest guide.

It is possible that some of the more intellectual parts of the problem may be simplified for both teachers and pupils. It is hoped that this book may be such an aid in one small corner of the situation.

In considering modern European culture (including that of North America) it is immediately apparent that the scientific attitude and method form a very large part of it. As J. W. N. Sullivan well says[§]: "The Spirit of the Age is something that practically all the intellectual life of the age has in common. It is not manifested only in philosophical treatises or in works of art; it is often manifested even more strikingly in statesmen's

* *Science and the Modern World*, Cambridge University Press, London, 1927, page 230.

§ *Aspects of Science*, First series, Cobden Sanderson, London 1923.

speeches and a country's domestic and foreign policy. It is a kind of intellectual and emotional atmosphere of which everybody is aware, but which probably nobody could define. We see, however, that a very important part of it consists in a sense of probability, of a tendency to accept certain kinds of explanation and to reject others.

"For the last few decades, at any rate, Science has been the chief factor in forming this omnipresent sense of probability. As a matter of fact, it is probable that the influence of Science in forming the Spirit of the Age can be traced a very long way back, as far as Copernicus."

Much the same idea is expressed by Whitehead in the preface of his book above referred to, as follows :

"The mentality of an epoch springs from a view of the world which is, in fact, dominant in the educated sections of the communities in question. There may be more than one such scheme, corresponding to cultural divisions. The various human interests which suggest cosmologies, and also are influenced by them, are science, aesthetics, ethics, religion. In every age each of these topics suggests a view of the world. In so far as the same set of people are swayed by all, or more than one, of these interests, their effective outlook will be the joint production from these sources. But each age has its dominant preoccupation; and during the three centuries in

question, the cosmology derived from science has been asserting itself at the expense of older points of view with their origins elsewhere."

This being so, it is important that the true meaning, scope and value of science should be better understood by every one. I do not at all intend to imply that science is or can be a solvent for all difficulties. It is only one part of the life of the world, and perhaps a small part. It is limited in content, in application, and in value. There are dangers involved in its unbalanced use. But it can be exceedingly useful in such world-wide and age-old problems as poverty, disease and agriculture, for instance. In order to be truly useful it must be better understood, and be put in its true place among other activities of the human mind and spirit. This booklet is an attempt to help teachers and pupils to make a sound estimate of it and thereby to make it as useful as possible.

The booklet is chiefly for Indian village school teachers, but partly also for those who train them and for their administrative officers or guides. Some parts of it will be more useful to one, and other parts to another group. Perhaps most of that part of the book after the exercises will not be immediately useful to most village teachers. The ideas in those later sections deal with the educational reasons for these exercises and their relation to the whole realm of education,

particular in countries in which science is not so much developed as in Europe and North America. These sections may prove especially helpful to training school or normal school teachers or to village school head masters.

Although the book grows out of the author's experience in India, it is believed that its conclusions and exercises will be found applicable, with minor modifications, in villages all over Asia, Africa, most of Russia, South America, Central America and Mexico. Indeed, because there is much misapprehension in regard to the real meaning and limitations and scope of science even in urbanized Europe and North America, and sometimes faulty methods of teaching science even in those countries, it is quite possible that the book might be useful even in those countries.

Perhaps it is foolish to load such large ideas and hopes on to such a little baby of a book, but I can only send it forth for whatever it may be worth.

Thanks are due to Mr. S. E. Stokes of Kotgarh for permitting me to develop and try out these exercises in his school there, and to my friends Mahatma Gandhi, D. B. Kalelkar, Biharilal, Chandmal, and Manmohan Ghose for their kind criticisms and suggestions, all of which have added value to the book.

Section One

The Origin and Nature of the Exercises

The following pages are designed to help overcome certain handicaps of Indian village children in relation to science study. Two and a half years' teaching in the Simla Hills district has clearly shown the author that the background of experience of these children is so simple and so different from that of Indian city-bred children or children in Europe or the United States, that all the Indian, British and American text books are almost useless. These books assume a familiarity with machinery of many kinds and with machine-made devices, appliances and products of all kinds,—a false assumption so far as these particular children are concerned. The vast majority of Indian village children are in substantially the same circumstances. Hence the phraseology, ideas, assumptions, reasoning, examples, and even pictures in the existing science text books mean exceedingly little to the children. Not knowing what it is all about, having no basis of familiarity, such books cannot be used to educate

the children in any true sense. Bewildered memorizing is the sole result, — not understanding. Furthermore the price of such books is prohibitive for village schools or village children.

The remedy does not seem to me to lie in Nature study, for various reasons. First of all, very few teachers, either Indian or European, in India, have the necessary knowledge, enthusiasm, ability to guide children amid the myriad things and events in nature, and the disciplinary power to keep order and make progress on expeditions out of doors. Furthermore, most of the courses in Nature study seem to me designed to or likely to result in merely stimulating wonder and curiosity and a hodge-podge of disconnected detail in the children's minds. In addition, Indian village children are quite familiar with Nature, though not with formal European concepts relating to it. The course of study prescribed by the Indian educational authorities does not leave much time for mere 'interest' studies.

Science is an aspect of things, events or phenomena which involves discovery, observation, statement, experiment, verification, and use of order, arrangement, sequences or laws in regard to the space and time relationships of those things, events or phenomena. It rests upon observation, comparison, measurement, controlled experimentation, classification, relation, generalization,

statement and record. Such formal attitudes, processes and methods are almost entirely new and strange to these children. They have done no thinking in abstractions. Causation, to them, involves either people, fate, magic, spirits or gods. Their senses are keen, but their powers of observation are largely undisciplined and have been kept in fairly narrow utilitarian channels, or confined by religious or fatalistic ideas of things and event.

Also I found, by comparison with children in the United States, a very great slowness, awkwardness and inaccuracy of manipulation and measurement in all the handling of rules, balances, instruments, pencils and drawing. Records were very dirty, crowded, poorly arranged, lacking in uniformity of arrangement, badly spaced, badly written, inaccurately stated, — slovenly in almost every respect. Of course it is not surprising, as all these things are entirely strange to them. With familiar village appliances they can be wonderfully skilful. Of course I realize that this was only a middle school in a corner of the country which is, in the aspect of academic education, somewhat behind most of India, and hence my observations cannot be generalised to apply to school children all over India. Yet from what I gather from experienced teachers from other parts of India, these faults are found, in lesser or greater degree, among a very large number of

Indian children. Indeed, they are frequent among village children in America, and I presume also in Europe, though not so bad.

It seems to me that before the children can understand or do any abstract thinking; before they can appreciate any concepts of natural laws; before they can get their minds into the attitude required by science; before they can appreciate and deal with the various properties of matter considered in science; they must undergo a fairly long course of practice in exercises which will develop and train their powers and instruments of perception (senses), their discrimination, skill of manipulation, perception of different kinds of order, arrangement and relationship between objects and their qualities. This training should be chiefly sensory and manipulative, with almost nothing expected from the children in the way of statement of results or description. It should appeal more to their subconscious than to their conscious minds. This will tend to develop unconscious ideas of order and relationship, and thus make possible for them to perceive and really understand 'laws' when they come later to the conventional, formal parts of science. This practice should also prepare the way for their understanding ideas of physical causation.

Section Two

Scope of the Book

This booklet, therefore, is not a text book for pupils, but for teachers. Nor is it a primer or book on elementary science. It is an attempt to help teachers to *prepare* the minds of their pupils for the subsequent study of science. If teachers do not see why any preparation is needed for science any more than for other studies, or why this particular method of preparation has been chosen or why they should not lecture to the pupils, they should read the discussion that follows the exercises.

Like all work for the ultimate use of pupils, these exercises require preparation first by the teacher, and it is assumed that he is willing to put in such work. For such preparation, it is hoped that the final sections may prove helpful, provided the teacher's interest and prior study have been sufficiently extensive.

The exercises are to be considered only as suggestions for teachers to use, develop, and adapt to local surroundings and circumstances as they may find best.

Section Three

Explanation of the Exercises

The following exercises were devised in order to give pupils sensory experience, practice, and manipulative training of a sort which would provide them with ideas and concepts of impersonal order, arrangement, relationship and laws. The teacher's explanations of what is to be done should be entirely oral. The teacher's work is supervisory and suggestive. The exercises are to be done by the pupils themselves, with perhaps one by the teacher to show them how at the start. But there should be no 'demonstrations' done only by the teacher, except perhaps near the end of the entire course, nor any lecturing or discussion except where specifically indicated in the exercises. He should not expect or ask for any oral or written statements from the pupils about the work, its nature, meaning, results or purposes, unless perhaps in response to a question by some pupil. He should, however, tell them at the start that the purpose of the course is to learn about order and arrangement in nature. He should have faith that

each pupil is thinking subconsciously and is forming in the subconsciousness the correlation and integration of understanding, responses, tendencies, attitudes of mind, expectancies, and familiarities which form a solid foundation for the later self-conscious grasp and formulation of scientific concepts of order and law.

The exercises are intended also to develop powers of alertness (both sensory and mental), sensitiveness, accuracy, speed, deftness, neatness, co-ordination and skill.

The experiments provide a good deal of practice in measurement, *after* the exercises in perceiving qualities, arrangements and relationships.

Attention is especially to be given to neatness and form of records at the stage when measuring begins.

It will be noticed that all the exercises in arrangements include both analysis and synthesis, a pulling apart and a construction, or a perception of a difference and then of similarity or unity. I believe that both these processes are necessary for a full understanding of any object or subject. Practice in seeing an underlying similarity or bond in spite of superficial difference or discrepancy is extremely valuable.

I hope that these exercises will provide a sufficiently rich and solid basis of sensory experience to support subsequent firm and clear abstract thinking and the attitude required in

science. If they, or any of them, prove too long, certain parts may be omitted. If desired, any entire exercise may be omitted, or the order changed. Any exercise may last more than one period. More exercises are provided than need be used in some cases, so that selection can be made according to circumstances. It is hoped that teachers will devise similar additional exercises more immediately adapted to their own conditions or better calculated to the purposes of the different groups of exercises.

The results of these exercises upon the two classes with which I tried them were satisfactory, but I was not long enough with these and other children to make definite comparisons and complete judgments. Nevertheless I feel sure that the idea is sound.

The apparatus required is exceedingly simple and inexpensive, and almost all of it familiar to village children. Most of it can be made by village carpenters, potters or blacksmiths, or obtained in village bazars or markets or in the fields.

The children must not get the idea that science means machinery or strange technology. Science is far broader than that, and applies just as much to village things, events, life and work as to mills, factories, machinery and Western environment. The great pioneers of science did their work and made their discoveries with very

simple apparatus. It is possible, therefore, at least to follow their footsteps and learn to do scientific thinking without much expensive or elaborate apparatus. After all, the student's mind is the most important piece of apparatus involved.

In regard to this last point we find the following passage in Prof. J. Welton's *The Psychology of Education*, Macmillan, London, 1923, at page 314:

"The use of complicated apparatus in a school laboratory is to be deprecated whenever the pupils are too young to grasp the systems of knowledge embodied in them. A great difficulty in scientific advance is always the invention of apparatus fitted to test a hypothesis. The great discoverers have always at first used apparatus which, as compared with later developments, was simple and rough. Scientific advance means increased perfection of apparatus as well as of thought. With rough apparatus no doubt the results are rough. But the educative aim is not a precise result in the demonstration, but improvement in the capacity of the pupil."

I do not want Indian village children to get the idea that science is only a school affair or only relates to shiny brass and glass devices and paraphernalia. I believe they can learn to think more clearly and to acquire a scientific attitude without all the expensive and complicated apparatus used in Western laboratories, or at least with extremely little of it. I want them to see that science is only one of the many aspects of the universe; that it is very useful

but not all-in-all; that it is not the same as machinery or Western technology; and that it is not in conflict with, but supplementary to, their religious and cultural background.

Care should be taken to have all the materials used familiar in the daily lives of the pupils, so far as possible. The treatment of topics should be thoroughly practical. That is, there should be a recognition of and practice in creating order and arrangement, rules and laws, in relation to the operations of providing food, clothing, and shelter, and beauties or aesthetic order in them all; in relation to such homely things as grain, milk, *ghi*, ~~butter~~ milk, fodder, fields, soil, manure, irrigation, rain, wells, weather, seed, plant growth, plant diseases, insects, birds, feeding and breeding of animals, qualities of cotton, wool, hemp, jute, strength of yarns, weaving, sewing, dyeing, ornamentation, pottery, wood, stone, bricks, masonry, carpentry, carving, strength of materials, building, basketry, tanning, marketing, wrapping or making up parcels for transport, methods of carriage on people's heads, backs, shoulders, by buffalo, donkey, mule, camel, elephant, ox-carts, etc.

Section Four

Variations in Exercises

The content and arrangement of the exercises are open to many changes and improvements. There is opportunity for much more material from the realms of biology, botony, zoology, astronomy, or geology, especially in the later lessons. Each teacher will wisely make his own adaptations suited to the local conditions and his own talents and experience and thinking. But whatever changes or additions are made, try to have the experiments show relations or patterns, rather than merely illustrations of qualities or new and curious phenomena.

Toward the end of the course much could be made of applications of the concept of radiant solar energy,—how it is the physical source of all life, activity and power; how the energy of wind, waterpower, wood-fire, coal, vegetable and mineral oils, were all derived from sunshine; how sunshine includes rays of heat, light and other less understood kinds all needed for health and life; how all plants and agriculture and hence all animal life depend upon it.

Hindu teachers will immediately see analogies here with the attitude expressed in the old Vedic hymns and *mantras*. Interesting experiments can be done by planting seeds in glass vessels and watching their growth and development under different conditions of warmth, light, soil and moisture.

There are three topics for possible development and research by normal school teachers, to come, perhaps, at the end of the course.

Graphs, as expressions of laws of functional variables, may be developed in very useful and interesting ways. Though usually taught as a part of mathematics, they belong just as much to science, and may be happily appropriated here. For suggestions see *Elementary Experiments in Practical Mathematics* by R. C. Fawdry, G. Bell and Sons, London; *The Teaching of Arithmetic* by F. F. Potter, Isaac Pitman and Sons, London, pages 305 and 437; *School Algebra* by A. G. Cracknall, University Tutorial Press, London, chapter on graphs.

The subject of Probability, both in its mathematical aspects and daily applications of commonsense critical judgment could be made a most valuable and interesting extension of these exercises, perhaps only for older pupils. So called scientific laws are only statements of strong probability, and a good understanding of the concept and applications of probability would be

a source of fine balance, perspective and practical ability in the mind of any and all pupils.

Another field rich in educational value and probably of immense importance lies in the relation of words and symbols and abstractions of thought to reality. Possible methods of practical educative work are suggested by Korzybski in his *Time-Binding, The General Theory*, Papers I and II (E. P. Dutton & Co., New York). See also *The Meaning of Meaning* by Ogden and Richards, Kegan Paul, London.

Section Five

Suggested Details of Practice of the Exercises

The first three days may be devoted entirely to demonstrations by the teacher of interesting, curious and, to the children, new phenomena of motion, light, heat, sound, magnetism, balance, structures, or space and time relationships. The object of these will be merely to arouse wonder, curiosity and interest in the new subject, but they are not essential and may be omitted. They are not really a part of the exercises themselves and so are an exception to the rule stated above, that all the work should be done by the pupils themselves. But if these preliminary demonstrations are given, they should as far as possible use familiar objects in ways which bring out unrealized qualities or relationships. Optical illusions in diagrams drawn on paper might be suitable as one of these demonstrations, a convex lens or burning glass another, a pendulum with varied weights and length of string perhaps another. Still others might be such as blowing soap bubbles with an old wooden cotton thread reel or spool; making a spectrum with a glass prism in a ray of sun-

light; changing the colour of moist *haldi* with a few drops of solution of baking soda; blowing the breath through clear lime water; showing the arrangement of iron filings on a piece of paper held close over a magnet; an explosion by grinding together a pinch of powdered sulphur and a pinch of potassium chlorate (*caution*, use only a very small pinch); making patterned ripples on water in a glass by causing the glass to vibrate strongly to a musical note; making a deep blue colour by mixing together weak solutions of ferrous sulphate and caustic soda.

The next four or five months might be devoted to the exercises themselves. Then, for the remainder of the year, perhaps experiments and discussion of heat and light, especially that of the sun and with special reference to their effect on plants, trees, farming and weather. The discussion of heat would find good applications for village boys in such matters as cooking, pottery making, blacksmithing, and clothing.

In the year following this course any regular or formal course in science may be pursued.

Although the pupils are usually referred to in the exercises as 'boys', the whole course is intended to be just as much for girls or classes of mixed boys and girls as for boys alone. Both can use science to advantage.

Section Six

Exercises in Order and Arrangement

I

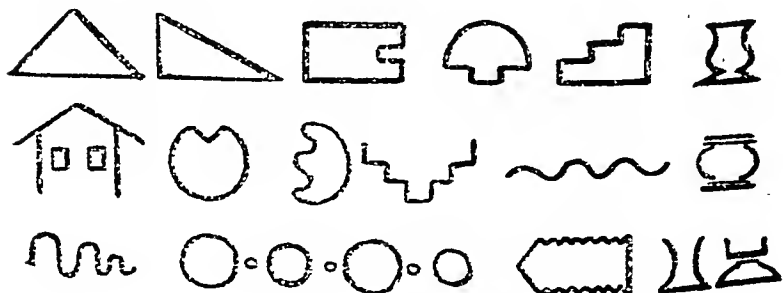
COPYING EXERCISES

For practice in accuracy of observation, accuracy of reproduction, neatness, speed, and thoroughness.

Have the class copy from a blackboard or from figures traced in the dust on the ground:

1. A set of about twenty figures arranged without regular sequence. For example; 9, 25, 6, 1, 37, 108, 19, 4, 1, 7, 29, 92, 87, 13, 5, 54, 53, 72, 11, 249, 333, 2654, 1234, 999.

2. Eight outlines or shapes or lines, to be copied freehand; such as



3. Five sentences in their vernacular containing some easy words that they all know how to spell, also a few words whose meaning they know when pronounced but whose spelling is unfamiliar to them, and perhaps three words entirely new to them but not long.

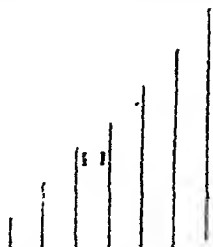
Repeat each set four times. Tell the pupils the purpose of the exercise before beginning. If they prove slow, careless, disorderly, dirty or inaccurate, give further practice other days, perhaps once a week, till they gain proficiency in all respects.

II

ARRANGEMENTS OF LENGTH

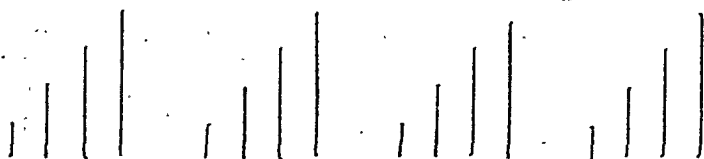
A. *Analysis*:

1. Draw on the blackboard or in the dust on the ground series of parallel straight lines of slightly and constantly increasing length, like these :



and ask the children to notice how the lines differ from each other, whether the difference is regular, whether it is an increasing difference or a decreasing difference, in which direction it proceeds (right to left or left to right).

2. Draw an alternate recurring series of straight parallel lines of different lengths, such as:



Ask them to notice the differences in this set also.

3. Ask them to give in their vernacular the names of plants, bushes and trees of gradually increasing height, one boy writing down, where all the others can see, these names as they are given and decided by the others.

4. In the same way work out the names of animals or birds or insects of gradually increasing length; or the names of the boys in the school arranged according to height, both continuously and in groups.

B. *Synthesis*:

1. Have the boys draw on paper or on the sand two series of straight lines similar to those given in A. 1 and 2 above.

2. Give to each boy a set of twigs or sticks or bits of stiff wire of different lengths, and have him arrange them in serial patterns of his own devising.

N. B. The teacher will notice here the first application of the terms *analysis* and *synthesis*, whose meanings were explained above on page 13. In the exercises in analysis the boys are separating

and dividing things, noticing the different parts or qualities of the lines that make up the patterns or objects observed. Under the synthesis problems they put such parts together to make larger units or patterns or groups. These two kinds of work are repeated in almost all the subsequent exercises.

III

ARRANGMENTS BY SIZE

A. *Analysis*: Separation of large from small.

1. Give each boy a handful of pebbles and have him grade them according to size, first in two groups, then in three groups, and then in continuous order so far as possible.

2. Do similarly with a handful of wheat, of rice, of *dal*, of beans, of soap nuts (*aritha*), or any other familiar small articles.

3. Do similarly with a little earth, sand or gravel, to be separated by shaking or winnowing.

4. Have the boys count the number of large leaves and of small leaves by groups on some plant or weed.

5. Discuss with them how such grading or arranging by size is done with different seeds, grains, fruits, nuts, etc.

B. *Synthesis*: Combination of large and small objects into larger wholes or unities.

1. Give each boy a tray or *thali* or plantain leaf containing about 20 beads or buttons or nuts.

of various sizes, at least four of each size, and have him arrange them into patterns of his own making, to be continued and varied as long as he can devise new patterns.

2. Have each boy name the small and large parts of his face or hand or foot.

3. Have them name kinds of work done at home that involve putting small things together to make a larger whole; for example, cooking, sewing, spinning and weaving cloth, building a house.

IV

ARRANGEMENTS BY SHAPE

(Plane)

A. Analysis:

Each boy is to be given a tray, *thali* or plaintain leaf full of objects to be sorted out into piles according to shape.

1. Pebbles; into round and angular shapes, or flat and bulky.

2. Leaves; into round and pointed.

3. Sticks; into straight, angular and curved.

4. Wire pieces; into straight, angular and curved.

5. Cardboard or sheet metal shapes, similarly, *e. g.*, rounded shapes, circles, squares, triangles, polygons.

6. Finally a tray full of many objects, — beads wires, buttons, seeds, nuts, pebbles, sticks, bits of

broken pottery, bits of metal or cardboard. These also are to be sorted by shapes, disregarding material, colour, or other qualities.

B. *Synthesis* :

1. Have each boy draw on paper or on the sand some shapes, each one different from the others. Then by repeating and combining those shapes let them make a pattern, repeating each pattern several times. Very simple shapes are best.

2. With straight or curved twigs or bits of wire have them make a pattern and then recurring patterns.

3. Similarly with pieces of cardboard or paper or sheet metal cut into duplicate or triplicate or more numbers for each shape.

4. Take some printed picture, such as is used in newspaper advertisements, cut it up into many pieces of different shapes, curved, angular, etc., mix them all together, and then have the boys fit the parts together so as to restore the complete picture.

5. Have each boy draw a set of five concentric circles, the radius of the inmost circle to be one inch, and the radii increasing $\frac{1}{4}$ of an inch each time. Use a pencil and a bit of string as a compass.

6. Let each boy, by the same means, draw a set of circles in a row, all of $1\frac{1}{2}$ inch radius, and just touching each other.

7. Do the same, but put the centres closer together and at a uniform distance apart, so that the circles will cut each other, all to the same extent.

V

ARRANGEMENTS BY NUMBER

A. *Analysis*:

1. Provide some patterns composed of dots on a sheet of paper and have them work out the sequences and write down the corresponding numbers. Of course slates may be used instead of paper. For example:

... .. The number sequence is 3, 3, 3,
 :: :: :: :: ::
 ::: :::: :::: :::: ::::
 : : : : : :
 :: :: :: :: :: ::

B. *Synthesis*:

1. Have them draw patterns composed of dots, of their own choosing, somewhat similar to the above examples.

2. With a pack of playing cards for each two boys, have them lay out the cards in sequences, by suits, by pairs, by fours, by colours.

3. Using dominoes or notched sticks, have them sort out the pieces by sequences, by pairs, etc.

For boys sufficiently advanced in arithmetic:

4. Have them work out by arithmetic several recurring decimals, and then make patterns with beads or pebbles of uniform size, making the number and order of beads in each separate group or element in the pattern correspond to the digits in the given recurring decimal.

5. Write on the blackboard or on the ground various arithmetic and geometric number series, and have the boys draw groups of straight lines to correspond; *e. g.*,

1, 2, 4, 8, 16, 32, 64.

1, 3, 5, 7, 9, 11, 13.

$1/2$, $1/3$, $1/4$, $1/5$, $1/6$.

VI

ARRANGEMENTS OF SHADE

A. *Analysis*, or separation :

1. Take a lot of pebbles, some light and some dark. Have the boys arrange them in groups of light and dark, perhaps two or three gradations; then by continuous gradation from the lightest to the darkest.

2. Do the same with a bunch of leaves, plant stems, or flowers.

3. Do the same with bits of wood, bark, paper, cloth.

4. Have them count and report the next day on the number of white, black and

motley marked cows in the village. Same as to dogs.

5. Have them arrange themselves in rows according to the shading of cloth in their *pyjamas*, caps, *sadaries*, etc. Of course if they all wear white, this will have to be omitted.

B. *Synthesis*:

1. With a lot of black and white buttons, nuts, beads or bits of paper or cardboard, have them make sequences, and recurring groups and patterns.

2. Similarly with bits of yarn or cloth, of different shades.

3. Using soft lead pencils, have each boy make a strip of shading on paper, slowly grading from white to black.

4. With coloured paper, cloth or yarn, each lot of different shades of one colour and a different colour to each boy, have them arrange the pieces in sequence from the light tints to the dark shades.

VII

ARRANGEMENTS OF COLOUR

CONTRASTS

A. *Analysis*:

1. Have the boys give the names of birds marked with two or more contrasting colours, naming the colours also.

2. Do the same for flowers, insects and animals.

B. Synthesis:

1. Give each child crayons of three contrasting colours and some squared paper (the latter is not essential), and instruct them all to make a repeating pattern, using at least two colours in each pattern.

2. Repeat, with three other colours.

3. Let the teacher with water colours make green by blending yellow and blue; purple, by blending red and blue; orange, by blending red and yellow; grey, by blending red, yellow, and blue. Then the boys are to do the same, either one at a time or all together if there are enough paints to go around.

4. Provided with a trayful of coloured bits of cloth, yarn, beads, paper or cardboard, have each child make a pattern, and then a recurring pattern.

5. Request each one to name and write down the names of all the different colours they know.

6. Have each boy, using only the three primary colours, produce different shades of some one colour. The method and principle is this. Red, yellow and blue are the primary colours and are complementary to each other in producing darker shades, *e. g.*, if a darker shade of red is

required, mix in some yellow and blue; similarly for blue, mix in some red and yellow in equal proportions, and so on. If a darker shade of green is required, mix in some red, as green is composed of blue and yellow. The principle is that the darker shade is a bit greyish, and grey is composed of yellow, red and blue in equal proportions; so if any of the missing colours from these three is supplied and rubbed in, a darker shade is produced.

VIII

ARRANGEMENTS OF COLOUR

HARMONIES

A. *Analysis* :

1. Request each boy to give the names of flowers, each of which has two or more tints or shades of the same colour in its blossom. If the season permits, ask them to bring specimens of them the following day.

2. Do the same in respect to insects, birds, and animals, but without attempting to bring specimens to the class.

3. Request them to name trees in order according to the shade of green in their foliage, beginning with those displaying the darkest shade first. Do the same for plants. Ask to have specimens of such foliage brought and arranged in class the next day.

B. Synthesis :

1. Have them make patterns with coloured crayons, or bits of cloth or paper, or leaves of different shades of the same colour.

2. Let them make three or four small round spots of any colour, gradually making the colour of deeper or darker shade by adding more and more of grey or black to the mixture.

IX

ARRANGEMENTS OF AREA

A. Analysis :

1. Give each boy some squared paper and have him count the number of small squares in a large square; in an oblong of given dimensions; in a tracing of map of some country spread over the squared paper; in a tracing of a circle similarly placed over the squared paper; in the tracing of a triangle.

2 Request each boy to count the number of bricks or stones or bamboos in a given area of wall surface.

3. On the blackboard or the dust of the ground, show how to divide a given polygon into triangles. Have them do likewise, first in front of the whole class and then individually on their own slates, pieces of paper or on the ground where they are sitting. They should divide the

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same polygon different ways; also different polygons. Do this for figures of 3, 4, 5, 6, 7, and 8 sides, both regular and irregular.

4. Do the same by paper folding.

B. *Synthesis*:

1. With small squares of stiff paper or sheet iron, have each boy build up squares, oblongs, and other figures of given dimensions. Where the figure is irregular, provide a blackboard diagram to be followed.

2. Have each boy draw on squared paper similar outlines, perhaps filling them in with pencil shading or coloured crayons.

3. Provide each boy with a considerable number of squares of stiff paper all of uniform size, and direct him to invent with them recurring patterns, as many as he can devise.

X

ARRANGEMENT OF VOLUMES

(*Three-Dimensional Shapes*)A. *Analysis*:

1. From a pile of many different-shaped wooden or clay blocks, have the boys select, sort out and put together in separate piles the cubes, oblongs, cylinders, cones, pyramids, spheres, and wedges.

2. Given a large cube made of smaller wooden or clay cubes, let them take it apart,

count the number of small cubes as a whole and in each layer and row; learning the arrangement by rows and layers. Each boy should do it by himself, repeating several times both with the original large-sized cube and then with other large cubes built up of the same small units.

Note: Short sections of bamboo will serve as cylinders, well formed carrots as cones, a cricket or hockey ball as a sphere; or these and other shapes may be made by the village potter or carpenter.

B. *Synthesis:*

1. Have the boys build cubes of different sizes from small unit cubes of wood or clay, also make oblongs out of unit cubes.
2. Teach them how to make cubes, oblongs, prisms, cylinders, pyramids, cones, etc., out of paper, and give them much practice in this.
3. Have them make clay models of all these shapes.
4. Bend a piece of wire into a semi-circle but with the two ends projecting in the same straight line; then, holding these ends twirl the wire rapidly so that it appears to form a sphere. Do the same with other outlines, showing how various solid figures may be generated by the movement of an outline around an axis. Then have the boys all do the same.

XI

ARRANGEMENTS OF ANGLES

A. *Analysis* :

1. Give the boys a considerable number of angular shapes made of paper, cardboard or sheet iron, the angles being multiples of ten degrees. Give them also a triangle of similar material with one of its angles exactly ten degrees. Using that as a unit, let them measure all the other angles.

2. Given an assortment of similar triangles, squares and oblongs, of different sizes, direct them to sort out the similar figures into separate piles.

B. *Synthesis* :

1. Have the boys draw squares of gradually increasing sizes.

2. Do the same with similar triangles.

3. With a carpenter's jointed ruler or any two wooden sticks joined together, indicate how angles of various sizes can be formed. Have each boy do likewise many times.

4. Given a considerable number of bits of wire bent into angles of five different sizes with duplicates of each size, let the boys construct figures or patterns, using the different sizes in recurring series. Have them try to build in this way triangles, squares, and pentagons, also irregular polygons.

5. Let them do paper folding exercises in making right angles and sub-divisions thereof.

6. Let each boy draw two concentric circles of one and four inches diameter, respectively, and divide the outer circumference by eight equidistant points. Upon these points and the inner circle let him then draw an eight-pointed star, using the inner circle as the base of the inner angles of the star. After it is complete, have him write the names or initials of eight points of the compass or quarters of the heavens at the appropriate points on the star.

XII

ARRANGEMENTS OF SYMMETRY

A. *Analysis* :

1. Explain symmetry, and show examples of symmetry around a point and around a straight line. Illustrate by the different parts of the human and animal bodies, of plants and insects.

B. *Synthesis* :

1. Give each boy some cardboard squares or buttons or beads or marbles, and have him make a considerable number of symmetrical arrangements around a point.

2. Do the same about a straight line as an axis,

3. Fold paper; cut out an outline on one side of the fold; unfold it and show the shape so formed, symmetrical about the crease as an

axis. Have the boys do this, inventing many different shapes.

XIII

ARRANGEMENTS BY WEIGHT

A. *Analysis* (To be done by pairs of boys, not individually) :

1. Give each pair of boys a couple of handfuls of pebbles. Direct them to separate the pebbles into two piles according to weight, doing the weighing first by estimation with the hands alone, then using simple scales.

2. Weigh out four piles of rice, wheat, sand or earth, 1 tola, 2 tolas, 3 tolas, and 4 tolas, respectively. Have the boys do the same, both for these quantities and others. Repeat with ounce weights if available.

3. Have each boy investigate among four of his neighbours and report the next day as to the number of seers of milk yielded each day on the average by each cow belonging to each of those four families.

4. Ask each boy to name three kinds of wood according to weight.

B. *Synthesis* :

1. Have the boys gather a number of stones and then place them in a line according to their weight, first in ascending order, then in descending order, then alternate light and heavy, then in recurring sequences.

XIV

ARRANGEMENTS OF SOUND

A. *Analysis*:

1. Ask the boys to give the names of birds with loud calls or cries and those whose notes are soft. Same for animals.

2. Have them name animals whose calls are high or shrill and those whose calls are low. Same for birds.

3. With a simple flute, fife or other wind instrument play notes of different pitch, then notes different in loudness. Let each boy do likewise. If possible, do the same with some stringed instrument and with a drum or *tabla*. Ask them to try to notice the differences in quality or 'timbre' between different instruments and different people's voices when singing.

4. Ask them to name all the different kinds of sounds and noises that occur in nature.

B. *Synthesis*:

1. Ask the boys to give imitations of different cries and calls of birds and animals.

2. Show them how all songs of men and birds are combinations or patterns or regular arrangements of sounds.

3. With some musical instrument play various patterns of two, three and four notes, ascending, descending, or uniform. Also play some patterns involving differences in loudness.

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4. Do the same by singing and then by whistling. Have each boy do the same.

XV

ARRANGEMENTS OF TOUCH SENSATIONS

Combined Analysis and Synthesis:

1. Blindfold each boy and let him feel with his fingers a number of objects of varying degrees of smoothness; and have him arrange them in order of comparative roughness while his eyes are still covered. Such substances as bits of bark of different trees and shrubs, pieces of wood of differing smoothness, various stones, etc., may be used.

2. Let each boy, with his eyes open, feel and then arrange in order of hardness a number of objects; e. g., cork, three kinds of wood, three kinds of stone, several pieces of cloth, a rubber eraser, etc.

3. Discuss with them different pairs of qualities detectable by touch: e. g., hard-soft, smooth-rough, sharp-dull (point and edge), rigid (hard)-elastic, wet-dry, oily-dry-rough, sticky-smooth, solid-liquid, brittle-ductile. (Elastic includes elasticity for bending, twisting, elongation, compression.)

Other substances for this exercise might be ashes, sand, clay, silk, cotton, wool, brass, lead, steel, *gud*, metal wire, both soft and stiff, sand-paper, feathers, leaves, thorns, burrs, seeds, pottery, paper.

XVI

ARRANGEMENTS OF TEMPERATURE

A. *Analysis*:

1. With the thermometer (using much care not to break it) have the boys find out and note down the temperature of the following:

a. The water in the village tank, at the top level; 3 inches below the surface; 6 inches below the surface; 1 foot below; 2 feet below.

b. The water of the irrigation well just as it comes to the top; after it has flowed 20 feet along the ditch away from the well; after it has flowed 50 feet away from the well. Canal water may be tested at different points from the main inlet.

c. Drinking water from the well or spring and put in a pot or *dekchi*; same after heating one minute over a fire; after thus heating two minutes; after heating 5 minutes; when boiling.

2. Let each boy take his own body temperature by placing the thermometer bulb in his closed armpit for 2 minutes.

3. Have the boys measure with the thermometer the air temperature in the shade in a house and then in the sunshine outside.

4. Using dried clay balls about egg size, keep one cool in the shade, expose one to the

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sunshine for half a minute, another for one minute, another for 2 minutes, and a fifth for 3 minutes. After such exposure, leave each boy test the temperature of every ball by closing his eyes and gently pressing or touching the ball into his eye-socket, a place which is very sensitive to heat.

B. *Synthesis* :

1. Have three *dekchis*, one full of cold water, one of boiling hot water and one empty. Measure the temperatures of the cold and of the hot water and record them. Then in the empty vessel mix about equal quantities of cold and hot water, and measure the temperature of the mixture. After the boys have watched the teacher do this, let them do the same, working by twos or threes together.

XVII

ARRANGEMENTS OF ODOURS

As the sense of smell is so slightly connected with space, this exercise cannot be considered as showing much about order or arrangement, but rather as stimulating the children's interest in one of the senses which is much used but little thought about. For the same reason there is no division of this exercise into analysis and synthesis.

1. Before the boys come, let the teacher prepare the experiment as follows. Cover the outside of about ten medium-sized bottles with

paper so that the contents cannot be seen, and number each bottle with a different number on its paper cover. Place in each bottle a little of some liquid or substance having a well-marked odour, a different kind in each bottle, keeping a private record of what is in each bottle but not telling the boys. Then when the boys come, tell them that each boy is to smell every bottle without saying anything or making any exclamation, is *silently* to guess what is in it, and write down on a piece of paper which the teacher will give him what his guess is for each bottle opposite the number of that bottle on his paper. After all have done this, let them compare their guesses and the teacher's list, and see who guessed most right. It is surprising to find how many errors are often made, even with familiar odours. For these substances you may use such things as kerosene oil, mustard oil, linseed oil, petrol, *ghi*, solutions of *gud*, *shakar*, and *chini*; milk, buttermilk (*chhash*), vinegar, mango pickle (*achar*), chillies, garlic or onion, fresh *pakodas*, a slice of radish (*mula*), a slice of carrot (*gajar*) or of turnip, or of citron; cinnamon (*dalchini*), cloves, monkey nuts, dried dates, tea leaves, a slice of lime or orange, any common flowers or bits of crushed leaves, bark or root, of any common aromatic herbs, shrubs or trees.

2. Discuss how people use the sense of smell to tell what is healthful or agreeable and what.

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is harmful; how animals use it to detect the presence of food, their enemies and their mates; how insects use it to find food and their mates.

XVIII

MEASUREMENT OF CERTAIN CHANGES

1. Using squared paper, let the boys keep a daily temperature record chart, recording the temperature at intervals of about two or three hours throughout the day. The boys might take turn in making the observations and recording the results, leaving it to the teacher to fill in the curve. The thermometer should of course always stay in the same place during the entire period.

2. Plant seeds of, say, wheat, barley, corn, gram or beans, in earth in glass tumblers, placing the seeds next to the glass in order to be able to observe developments; cover the outside of the glasses with dark or thick cloth or paper; keep the earth moist and slightly warm; remove the cloth daily for a few minutes, note, measure (as accurately as possible) the growth of root and stem separately, and record results for each plant. Before planting, weigh each seed and then at the end of the period wash each plant free from dirt and weigh again and compare with the weight of its seed. All of this is to be watched by all the boys.

3. Hang a string in a concentrated solution of ordinary salt. Keep the solution always concentrated. Weigh the growing crystal daily and record the increase. Do the same with a sugar solution. Call the attention of the boys to the different forms of the crystals. Perhaps do the same with iron sulphate or copper sulphate or any other easily procurable salts. All of this to be observed by the boys of course.

4. During the rainy season keep a record of daily rainfall in a pail or some similar vessel as a rough rain gauge.

5. Record the heights and weights of each boy in the class at the beginning, middle and end of the year.

XIX

ARRANGEMENTS OF TIME

A. *Analysis* :

1. With a watch (secondhand) let each boy count and record the pulse of three other boys. Compare the pulses of the whole class and get the average.

2. Have each boy, with a watch, time separately three other boys in doing the addition of a column of about ten figures, using the same figures. Compare the results of the whole class.

3. As in the first experiment above, let each boy note and record the rate of breathing

of three other boys. Have them compare results for the whole class.

4. Ask the class to name a number of quick events in nature, such as lightning, a wink of the eye, the wing beat of an insect, the jump of a flea or grasshopper. Similarly a set of slow events; *e.g.*, the seasons, ripening of grain, movement of a snail or turtle. Have them make a list of the ripening times of various grains and vegetables and arrange them in such time order.

B. *Synthesis*:

1. With a stick on the floor or on a board or piece of metal, illustrate various drum beats and rhythms. Have each boy do the same.

2. Let each one develop drum rhythm patterns, combining slow and quick strokes.

3. Ask them to name all the time divisions or parts of the day, the week, the lunar month, the year.

4. Let them name as many ways of measuring time as they can think of; *e.g.*, wink of eye, pulse, movement of shadows, daylight, physiological changes in processes of growth and aging, etc.

5. Devise some experiments with a simple pendulum made of a stone tied to a string, varying both the length of the string and the weight of the stone, and noting the effect on time of swing.

6. Have each boy plan out and write down a schedule of work and events for the forthcoming day, naming each event in the order of its probable occurrence and the length of time probably required for it. On the following day he should check it up in detail and note all variations from the plan. Repeat several times. Do the same for a full week, but only for the major events.

XX

ARRANGEMENTS OF TIME AND SPACE

COMBINED *i. e.*, MOTION

A. *Analysis* :

1. Ask the boys to name and classify animals into those which are slow and those which are quick moving.

2. Do the same with birds and insects.

3. Have them name and grade the various fast working and slow working craftsmen and labourers in the village.

4. Let them name and grade the boys in the whole school according to their speed in running.

5. Have them classify and arrange all kinds of farm work according to speed, *e. g.*, ploughing, harvesting, milking, grinding *ata*, husking rice, planting, irrigating, etc.

B. *Synthesis* :

1. Show how walking is a pattern of motion; up, down, forward and back.

2. Have the boys name dances in which there are combinations or alternations of slow and fast steps or motions. If possible, let them illustrate these.

3. Explain how all the following changes may be considered as recurring patterns:—variations of the shadow cast by the sun at different times of the day and repeating day after day; changes of temperature during each day and during the year; growth of plants from year to year; the motion of the sun, moon and stars; change of phases of the moon.

XXI

COMPOUND ARRANGEMENTS

At the teacher's discretion, he may work out and have the boys do various exercises in compound arrangements involving two elements, such as:—

Length and direction,
Shape and position (symmetry),
Size and position,
Area and shade,
Area and colour,
Length and area,
Shape and area,
Time and sound (music).

XXII

COMPLEX ARRANGEMENTS

A. *Analysis and Synthesis Combined:*

Finding similarities in apparent differences. Give each boy a handful or trayful of many objects different in respect to colour, size, shape, weight and use. Have him first note and state the differences and then sort out the objects into groups or sequences, first according to one quality, then after mixing them up again, re-sort according to some other quality, *e.g.*, first shape, then by weight, etc., going through the whole set of qualities common to the articles.

2. Give each boy a trayful of objects all unlike except in respect to weight, that is all of the same weight but of different colours, shapes, uses, sizes, etc. Have him find out and name the one quality common to all.

3. Same, but having some other quality, not too easily noticeable.

4. Same, as No. 2, except that the weights are in an increasing sequence. Have him solve the problem in arrangement, and actually lay them out in order according to weight.

5. Discuss with the class the grading of seed according to size, shape, hardness, colour, and appearance of parent plant, and of other seeds in the same cluster. Then, if any crop in neighbouring fields is nearly ripe, go there and select the best:

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samples of the given kind of seed; that is, have the boys do it. If no crop is ripe, do some selecting and grading from any lot of dry stored grain available.

6. In time of harvest have the boys do similar judging and grading of any fruit grown in your locality.

7. Discuss the judging of cattle according to conformation and size of different bodily parts (such as udder, mouth, girth, etc.) and then give each boy practice in this on the village cattle, checking up results by finding out the actual milk yield of the cows judged and the draft usefulness of the bullocks.

8. Choose any given quality pertaining to a given group of objects; say, colour of insects. Then have the boys name all the insects they can think of which have special colour chosen. Do this in respect to birds, animals, plants, trees, stones, soil, people, grouping them, for instance, by colour, tallness, weight, method of locomotion, selected parts of structure, food habits, usual location, speed of motion, type of noise made, hardness, length of life, uses to man, etc.

XXIII

CLEANNESS AS A KIND OF ARRANGEMENT

A *Analysis*:

Discuss with the class dirt and cleanness, and show them that cleanness is really a separation

of different kinds of matter into different places, chiefly for the sake of better functioning of some sort. Cleanness of the body is to promote better bodily functioning, *i. e.*, health. Cleanness and good order in a library is so as to make the books more easily available and thus more useful to all users of the library. Cleanness is a putting each kind of matter in the place where it can be most useful and least harmful. For example; sifting or winnowing the chaff and sand from grain, washing rice before cooking, filtering water with a cloth, putting cowdung in special piles near the cow-shed or in the fields, washing one's hands before eating.

Show how what is 'dirt' or poison or waste matter for one kind of life is food or means of life for another. For instance, human excrement is waste and poison and repulsive to mankind, but it is food for all plants and vegetation and for flies and some other insects. And in turn, the leaves of all plants are steadily giving off oxygen gas, a sort of waste product to the plant, but the life-giving part of air for mankind and animals. Hence, nothing is absolutely impure or filthy; it is merely a matter of *order*, of putting the right thing in the right place.

Explain, then, that by the right placing or use of 'dirt' or 'filth' we can guide life and make our surroundings healthy and increase our wealth. If we leave filth scattered around in our

houses or on the streets or anywhere on the ground, it breeds flies and other vermin which carry filth on to our food and bodies and make us unwell and uncomfortable. But if such filth is immediately buried in the fields and gardens, no vermin is created, we are more healthy and our plants yield more and better crops. Also, by not creating harmful forms of life, we avoid the tendency or need for *himsa* later upon such vermin in order to preserve our health or life. This makes all life more harmonious.

Explain the natural and inevitable sequence of trouble arising from uncleanness. For instance, leaving dust, refuse or bits of food on the floor and in the corners of a room causes odours. This attracts flies. Spiders soon notice the presence of many flies and so begin to make their webs. Toads or lizards also come to feed on the flies. Snakes follow in order to feed on the toads or mice or lizards. Or rats come to feed on the refuse. Rats bring fleas, and the fleas carry the plague. The flies carry the germs of cholera, dysentery, typhoid, etc., on their feet, walk on our lips, fingers and food, and thus spread many diseases. Between all these different kinds of vermin, the people in the house are made uncomfortable and unwell. Good order and cleanness are better. Discuss also keeping the body internally clean. Weeds as disorder in a field or garden.

Practice :

Take the children to some dirty or untidy place near by, point out the various kinds of disorder there and how they interfere with the best activities for which that place is designed and with the health of people there and near there. Then have the children clean it very thoroughly and arrange all the objects there in good order.

XXIV

DISCUSSION OF THE SENSES

By this time the subconscious sense of order and the meaning of arrangement ought to have become sufficiently established in the pupils so that they are ready to bring it fully into conscious realization. From now on the teacher may therefore discuss the subject in its many aspects, as well as carry on various practical exercises.

By questions and supplementary information from the teacher let the class work out the names of all the senses and write them down before the whole class. They should of course include sight, hearing, touch, taste, smell, temperature discrimination, kinesthetic (sense of motion), balance, and articular (sense of position by means of joint and muscle movements). Also work out and state names of the organs or means of perception of each sense.

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Discuss all the different features that are perceived by each sense. For example, the eye perceives light, shade, distance (including length, width, height or thickness), area, colour, and the combinations of these which make up size, shape, perspective, etc. The ear perceives pitch, loudness, quality (timbre), and distance away and direction of the source of the sound. Touch yields many other items of sense knowledge. Work out for each sense.

In a subsequent lesson explain and illustrate various illusions of sight and the other senses. Also discuss the relative accuracy of the senses, the number of separate discriminations it is able to make within its own field. Also consider whether the senses may be trained to greater sensitiveness, accuracy and sureness. Which sense is most educatable? Explain how the eye is so important to science because it can make such exact quantitative comparisons.

Tell the children how some insects and animals apparently have other senses which are either missing or very rudimentary in man; e.g., perhaps a sense of atmospheric moisture, of air-pressure (as indicated by the apparent ability of spiders, ants and bees to foretell the weather). Also how such other creatures seem to have a wider range or greater delicacy and accuracy than man has in respect to certain senses. For instance the marvellously keen sense of smell

among bees; the keenness of vision of kites, hawks and eagles; the wide range of hearing among bats; the sense of smell among dogs and many wild animals; the delicate temperature sense of insects.

XXV

MEASURING

A. *Analysis*:

Discuss and illustrate the following topics:

Different kinds of quantities capable of measurement; distance (including length, width, height, thickness), area, volume, time, weight, speed, direction (angles), heat, money, etc. Certain qualities which can be compared but are difficult to measure quantitatively, such as smells, sounds, colours, tastes. Grading of grain, seeds, fruit, potatoes, cattle, sheep, goats, etc.

Explain measurement as a ratio or comparison with an arbitrary standard unit. Bodily standards,—the foot, *gaz* (cubit), pace, span, hand, width of fingers, handful, pinch (of salt), wink of eye. Decimal system founded on ten fingers, digit means one finger. Various standards used in different countries, Indian, English, metric, etc. The qualities of accuracy, convenience and necessity in relation to the standard unit used in any given situation. Pace off on a maidan a rod, a surveyor's chain, a bigha, etc.

Sources of error in measuring, from inaccuracies of our senses, from awkwardness or difficulties of manipulation, from outside disturbing influences, etc.

Importance of measurement in regard to *order* and hence in relation to science.

B. *Instruments* :

Have the boys make measuring rulers and protractors from paper, first by folding and then by marking with pencil and pen. Test their accuracy. Have them make a series of standard weights with sand or earth in cloth bags. Also a rough beam balance. Also a plumb line; a pendulum; a sun dial; a rough water thermometer; a compass with string and pencil. Consider the use of a shallow basket for winnowing and cleaning grain. Possible devices for rapidly grading seeds, fruits, etc. according to size.

C. *Practice (Synthesis)* :

1. Have the class engage in numerous competitive contests in guessing or estimating lengths and heights of buildings, trees, maidans and other open spaces, distances along roads, heights of persons, size of different bodily parts; also weights of different objects and people and of quantities of grain in piles.

2. Let them practise a fair number of measurements with the instruments which they have made.

3. Direct each boy to count the number of threads per inch in length and width of the cloth of his *dhoti*, *paijamas*, shirt, or other piece of cloth.

4. With wooden rulers graduated into tenths of an inch they should be given much practice (at least 15 periods) in measuring accurately straight lines, sides of squares and oblongs, sides and altitudes of triangles.

5. With yard sticks let them measure the dimensions of various rooms and small buildings. With a rope, strong cord or surveyor's chain have them measure and calculate areas of several maidans and fields.

6. They should learn by heart the usual tables of measurement; Indian, English, metric, —for length, area, weight and time.

7. With a protractor pasted or tacked on a board, and a plumb line and rough level made with a bottle and water, let them test various floors, walls and posts for trueness as to horizontal and vertical direction and the amount of error.

8. With their self-made pendulum, corrected by a watch, let them measure the duration of various events, such as twenty five heart beats, ten breaths, walking a given distance visible from the place of the pendulum, etc.

9. With the balance they have made and their unit weights, have them weigh a considerable

number of familiar objects and quantities of grain and other materials and supplies.

10. After learning how to measure the volume of a cube, and learning tables of cubic measure, have them measure a number of cubes of different size made of clay or wood. Then let them measure the volume of oblong wooden blocks, bricks, boxes, rooms.

11. Show them how to measure volumes of small irregular solids by displacement of water in a jar, and let them so measure the volume of stones, small metal objects, etc.

12. If a microscope or simple convex lens is obtainable, let each boy examine with it the skin of his hand, bits of grass, leaves, insects, pebbles, a drop of muddy water etc. Then, referring to the sizes of different units in different scales of measurement, discuss the matter of accuracy of measurement in relation to the instruments used, the purpose for which the result is to be used, etc. If the boys have studied decimals in their arithmetic, the matter of significant figures may be discussed. Sources and probability of errors may be briefly considered.

Exercises in measurement may be extended almost indefinitely. Any text-book on mensuration will suggest many more problems. Elementary surveying of land is excellent work for the boys in this connection. Possibly the services of the local surveyor might be enlisted for this, if he

is good-natured; or the teacher may obtain one of the text-books used for this in the Boy Scout movement, and work it up himself.

XXVI

DISCUSSION OF ACCURACY

After considerable practice in estimation and measurement of various kinds, discuss again with the boys the relative accuracy of the different senses, how accuracy may be developed by training, the need for care, the place and importance of records. The senses as instruments of knowledge. At this point more practice may be given in estimation of all kinds.

Distinguish and make clear to the boys the difference between accuracy of observation and accuracy of statement and accuracy of reproduction. At the discretion of the teacher some consideration may be given to the topics of probabilities of error, sources of error, percentage of error, approximation, omissions, significant figures.

Talk with them about such matters as carefulness, speed of observation, attention to detail, records as an improved form of memory (for scientific work), neatness in making records, care of records, the humility engendered by science by the realization of the inevitability of inaccuracy in all matters of human observation, statement and thinking based thereon.

XXVII

FORM AND ARRANGEMENT OF RECORDS

The form and arrangement of all written statements, records, maps, plans, graphs, descriptions, etc., may be considered as a valuable and constantly used exercise in one kind of order. It is therefore given in detail, but as it required so much space, it has been placed at the end as an appendix.

XXVIII

STATEMENTS OF ORDER *i. e.*, SCIENTIFIC LAWS.

A number of experiments may now be done by the teacher alone, but preferably by the boys also, and then the boys be required to try to state in words, and perhaps reduce to an algebraic formula in some cases, the order of the events of phenomena which they have observed. This will then constitute a rule or law of what took place on that occasion. Later they may discuss whether they believe the rule holds good in all cases.

The following are suggested as being suitable for this purpose :

1. Ask them to state the order in which the colours occur in a rainbow. Is it always the same ? Show them repeatedly a spectrum made by a glass prism and a ray of sunlight. Is it the same as in the rainbow ?

2. By means of a mirror stood upright on a piece of paper, a small object and a lead pencil to trace the lines of vision, develop the fact that the angle of incidence is equal to the angle of reflection, and have each boy state it in his own words.

3. With a string and stones of various weights develop the law that the time of swing of a pendulum varies directly in relation to the length. The exact statement of the law should not be required or even mentioned, as it is too complex for them at this stage.

4. Bore a hole at the middle point of a metre stick, and get two tin can covers of equal size and weight, and with thread or string make them into movable suspended pans for a rough scale balance. With this apparatus and some tola or ounce weights work out the law of the lever: $W^1 \times D^1 = W^2 \times D^2$

5. If the teacher is familiar with musical notation, he may write down a bar of some familiar tune or rag as a statement of the law governing the relation between those notes.

6. A rough sonometer may be made and the relations between the notes sounded and the length of vibrating string worked out.

XXIX

DISCUSSION OF ORDER

It will now be profitable to discuss with the class the whole idea of order, arrangement,

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sequence and pattern, to bring out explicitly the full meaning of what they have been doing and how it is related to the formal science which they will study later. The discussion will, of course, have to be simple, and illustrated by homely and familiar examples.

Explain how there are many different kinds of order in the world, giving examples of each. These should include the following: historical (temporal); functional (for a particular use); political; moral and spiritual; aesthetic (beauty); mathematical (number and form); physical; logical (for thinking and statement).

Law as a statement of order or of arrangement or pattern. Living organisms as a sort of pattern. A law implies uniformity and repetition and sequence.

Classification implies repetition, order, pattern, grouping. It is partly based on measuring, partly on recognizing differences and similarities (relationships).

Science as the discovery and use of certain kinds of order, arrangement or pattern.

Causation as knowledge of details of certain apparent uniformities of order in relation to events.

XXX

WHAT IS SCIENCE?

Before talking this over with the boys, it would be well for the teacher to read most

of the section following this set of exercises. Each teacher, knowing his class and their surroundings, will devise a separate method of approaching and handling this talk. Below are given some brief suggestions as to ideas which might be developed and included in the discussion. The boys should be encouraged to ask questions and go into as many details as they desire, compatible with the discussion. It may, of course, last several days.

The discussion may include ideas of order; law; measurement; comparisons with other kinds of order; usefulness to man; science is concerned chiefly with non-personal things or non-personal aspects of human beings; also it is concerned chiefly with space-time quantities and qualities; classification; verification by experiment is a characteristic of the more exact sciences; it is concerned with principles capable of verification by experiment; control of conditions in an experiment; hypothesis; theory; cause and effect; difference between one thing simply happening after another in point of time, and one thing happening *because* of another thing; that is to say, the difference between mere sequence in time without unvarying uniformity of repetition, and mere sequence in space (pattern or design), and causation (uniformity of repetition of detailed known sequences of events. Probability. Science tries to learn and explain the *how* of events and phenomena, but not the *why*.

Difference between science and art, between science and technology.

XXXI

SCIENCE IN VILLAGE LIFE

Discuss with the class how matters of order and arrangement enter into and are a part of all aspects, elements, objects, circumstances and occasions of village life; and how careful study and observation of such order may lead to discoveries of more perfect order, and thence to a more prosperous and better life for all. Show applications of order and science in all the different village occupations:— cooking, spinning, weaving, agriculture in all its branches, silk worm culture, feeding and breeding of animals, irrigation, digging and repairing wells, house building, carpentry, pottery, dyeing, medicine, tanning, shoe-making, basketry, making *gud*, oil pressing, gold and silversmith's work, packing and carriage of goods, preservation of grains and fruits, writing, shaving and cutting of hair, midwife's work, blacksmithy, roof thatching, fruit culture and gathering, making fires, scavenging, cleaning the rooms and surroundings of the house, washing of utensils and clothes, bathing the body, cutting and piling wood, fetching and storing drinking water, treatment of bodily injuries, preparation and storing of manure and cowdung cakes for fuel, digging and repair of irrigation.

ditches, etc.. Show how skill is the understanding and habitual use of knowledge of these kinds of order.

Make it clear to them, that if we will think of it, science may enter into and may be used to improve all the material part of our lives. That although Western nations have used science to make many machines and develop much power; yet science, order and skill do not necessarily mean or require big metal machines or steam engines or electricity. That science is a very useful tool, but its possession and use does not make any man or boy a better person morally, or superior to his parents relatives or others, and does not make any nation using it morally superior to others which use it less.

Get them to realise that for thousands of years their forefathers have been carefully observing the operations of nature and the qualities of things and different forms of life; and that in so far as they discovered and used the orders there existing they were using science, even though they did not realize it or call it by that name. Hence they discovered much that has been of great use to us all, and even many things that the Western scientists have not yet discovered. But no nation or group of workers has discovered or ever will discover *all* scientific truths. Each race and country has its own special forms of skill and has made discoveries very useful

to its own environment. Nobody should boast of his own, nor on the other hand despise his own as too slight or useless. The methods, tools, beliefs and customs of our forefathers were not necessarily good just because they were ancient, nor were they, on the other hand, necessarily bad or unscientific. Much of the ancient knowledge has been lost, but much of it can be rediscovered, especially by the aid of science. Science applies to all things, to all forms and degrees of physical power and energy, and to all modes of technology.

Section Seven

Some Questions

When first faced with the problem and while planning and trying out the foregoing exercises, various queries arose. Was it fair to try to teach science to these boys in their simple environment, anyhow? Was it not imposing on them something of no present or future use or value to them in their circumstances? Does the true soul and mind of India care for or desire Western science? If the children were successfully taught science, might there not be a danger of upsetting their whole cultural and religious attitude and poise and outlook on life, without giving them any sure foundation in return? Might it tend to make them scornful of all the ancient Indian ways of work and life, both those which are sound and those which are open to improvement, and perhaps make them want to ape all Western modes, irrespective of their soundness or adaptability to India? And if science is to be taught to them, why can it not be

begun just like any other study? Why is any preparation needed before the elementary part of science is begun? After all, was not my experience too short and limited in place and scope to provide a sound foundation for my ideas?

It may well be that many Indian educationists and village schoolmasters have felt these same doubts and struggled with the same difficulties. Hence, I offer for their use not only the concrete exercises I worked out, but also the answers I found to these questions, my reasons for adopting this particular method, and my ideas as to the relation between this little course and some of the larger matters of modern education, particularly in India.

Section Eight

Consideration of Doubts and Questions

1. *Value of Science to Village Children*

Let us proceed to the discussion. First of all, what is the use of trying to teach science to Indian village children?

I do *not* encourage it on the ground that it will help boys to get positions either with the Government or with private factories, mills or other industrial establishments in cities. Education for such jobs, in the present state of affairs in India, leads only to more middle class unemployment. Nor do I believe in educating children to think that they are superior to their parents or to their present environment or group. If boys desire Government or industrial positions, of course any good teaching will help them, but that fact is not here advocated as a reason for the study of science.

Science study seems to me to have three advantages for Indian village children, even though their lives are so simple and remote from Western machine-driven ways. One use lies in

the fact, already mentioned in the Introduction, that only as Indians truly understand science can they wisely decide what parts of it or of its products and results they may wisely take over and incorporate into their culture. The conflict of Western and Eastern cultures is a fact which penetrates even into the villages and profoundly affects life there. In all cultural contacts in the past there has been the chance of newer and finer civilizations arising from the inter-fertilization of ideas and ideals and the evolution of new modes of living. If the process can become partly conscious, or self-conscious, and wise selections and adaptations be made, there is better promise of a happy future for India. And as ninety per cent. of the population live in the villages, the majority of Indian leaders of the future will probably be of village origin. Hence, the education of village children is very important.

A second advantage of science is its practical usefulness. Even though India may not want to adopt and develop a materialistic civilization, yet if she is to regain a strong sense of national dignity and self-respect it would seem to be necessary to do away with much of the present appalling poverty and ignorance among the masses. Part of the trouble lies with defects of economic distribution, but much is also due to inefficient production. Material improvement in certain

respects is imperative, and it would be a weak mistake to expect the advance to come from Government.

There must be improvements in agriculture, hygiene and public health, hand-spinning and hand-weaving, and probably the technique of road making and repair, paper manufacture and printing, and the processes of metallurgy and tool and machine manufacture needed in these arts at least. Thus there is a whole world for the useful application and practice of science in the villages. An expansion of the foregoing topics would mean such things as good wells both for drinking water and for cattle and irrigation; mechanisms for raising such water; cattle breeding, feeding, and management; tanning of leather; development of Chinese or allied methods of producing manure; cotton technology; seed selection; control of malaria, cholera, typhoid, plague, *kala azar*, dysentery and other diseases; improvements in cooking and dietetics; revival and betterment of ancient processes of dyeing, paper making, and metallurgy.

Science can be a great aid and stimulus to all this. Whether India greatly develops and utilizes coal and petroleum as sources of power, or relies more on the improved utilization of solar energy through efficient manual labour,* she must develop more material power in order to

*See my book, *Economics of Khaddar*, S. Ganesan, Madras, 1928.

get out of her present slough of poverty. Science may be a means to that end.

Thirdly, science has certain intrinsic educational values of its own. The attitude of mind it develops, the discipline it requires, are of themselves good, and will enable their owners better to cope with their environment and with the international and intellectual world forces of today and of the future.

Shri Aurobindo Ghosh, in his essay on *Materialism** gives his estimate of the value of science, in part, as follows:

"Not only has it immensely widened and filled in the knowledge of the race and accustomed it to a great patience of research, scrupulosity, accuracy,—if it has done that only in one large sphere of inquiry, it has still prepared for the extension of the same curiosity, intellectual rectitude, power for knowledge to other and higher fields,—not only has it with unexampled force and richness of invention brought and put into our hands, for much evil, but also for much good, discoveries, instruments, practical powers, conquests, conveniences, which however we may declare their insufficiency for our higher interests, yet few of us would care to relinquish; but it has also, paradoxical as that might at first seem, strengthened man's idealism. On the whole it has given him a kindlier hope and humanized his nature. Tolerance is greater, liberty has increased, charity is more a matter of course, peace, if not yet practicable, is growing at least imaginable.

"Science is a right knowledge, in the end only of processes, but still, the knowledge of processes too is a

*Published by Arya Publishing House, College Square, Calcutta.

part of the total wisdom, and essential to a wide and clear approach toward the deeper Truth behind.

"Man does need to develop firmly in all his earthly parts, to fortify and perfect his body, his life, his outward-going mind, to take full possession of the earth his dwelling place, to know and utilize physical nature, enrich his environment and satisfy by the aid of a generalized intelligence his evolving mental, vital and physical being. That is not all his need, but it is a great and initial part of it and of human perfection. Its full meaning appears afterwards; for only in the beginning and in the appearance an impulse of his life, in the end and really it will be seen a need of his soul, a preparing of a fit environment for a diviner life. He has been set here to serve God's ways upon earth and fulfil the Godhead in men, and he must not despise earth or reject the basis given for the first powers and potentialities of the Godhead.

"Three things will remain from the labour of the secularist centuries; truth of the physical world and its importance, the scientific method of knowledge, — which is to induce Nature and Being to reveal their own way of being and proceeding, not hastening to put upon them our own impositions of idea and imagination, *adhyaropa*, — and last, though very far from least, the truth and importance of the earth life and the human endeavour, its evolutionary meaning."

Another good statement of the value of science as a study is found in Dean Inge's essay on *The Training of the Reason*,* pages 267-268:

"Of the teaching of science I am not competent to speak. But as an instrument of mind-training, and even of liberal education, it seems to me to have a far higher

* In *The Church and The World*, Longmans Green, London, 1927.

value than is usually conceded to it by humanists. To direct the imagination to the infinitely great and the infinitely small, to vistas of time in which a thousand years are as one day; to the tremendous forces imprisoned in minute particles of matter; to the amazing complexity of the mechanism by which the organs of the human body perform their work; to analyze the light which has travelled for centuries from some distant star; to retrace the history of the earth and the evolution of its inhabitants—such studies cannot fail to elevate the mind, and only prejudice will disparage them. They promote also a fine respect for truth and fact, for order and outline, as the Greeks said, with a wholesome dislike of sophistry and rhetoric. The air which blows about scientific studies is like the air of a mountain top—thin, but pure and bracing. And as a subject of education science has a further advantage which can hardly be overestimated. It is in science that most of the new discoveries are being made. The rapture of the forward view belongs to science more than to any other study. We may take it as a well-established principle in education that the most advanced teachers should be researchers and discoverers as well as lecturers, and that the rank and file should be learners as well as instructors. There is no subject in which this ideal is so nearly attainable as in science."

The value of science is discussed also by Mr. J. W. N. Sullivan in his *Aspects of Science* (Cobden Sanderson, London, 1923), at pages 11 and 13. He says:

"With the construction of theories science enters on a new phase in its development, and serves a different set of human values. Its facts, the products of local curiosities, now take on an order, and serve the desire for

comprehension. The apparently dissimilar becomes related; law supervenes on chaos. The desire for knowledge becomes transformed into the desire for *significant* knowledge—significant primarily for contemplation, and secondarily for practice. It is the scientific theory alone that gives to science its true being and makes it worthy of a deep concern. The desire for comprehension is deeply rooted in human nature. Religious myths and philosophical systems arose in obedience to this impulse. Science also exists to satisfy this craving.

“Besides serving curiosity, comprehension and practice, science offers richly satisfying objects to the aesthetic impulse. The matter of the highest art, like that of true science, is reality, and the measure in which science falls short as an art, is the measure in which it is incomplete as science.”

The poet Tagore, in his *Creative Unity* (Macmillan, New York, 1922) remarks that “science, through mastery of laws of nature, is to liberate human souls from the dark dungeon of matter.”

If the reader still has doubts as to the value of science for Indian village boys, I would refer him to the writings of such men as Sir J. C. Bose, Thomas Huxley, Sir Ray Lankester, J. A. Thomson, Lord Kelvin, Faraday, J. W. N. Sullivan, J. S. Haldane, Edison, A. N. Whitehead, Bertrand Russell, and a host of others.

2. *Possible Dangers in Science*

Now comes the query whether science might not harmfully disturb the balance and harmony of the religious and cultural background of Indian

children. Might it not tend to destroy old faiths and folk-ways, even tend to put an end to a belief in God or in the spiritual and moral order of the world?

In its former dogmatic days science did often have such an effect on people in the West. But of recent years science has come to realize better its limitations and now it is far more humble, less dogmatic, more companionable and tolerant of other ways of looking at life and the world. It is now realized that science is a study of the *structure* of the time-space world. It tries to answer the question *how* in mechanical, structural, organic, or relational terms, but cannot deal with the deeper questions of *what* and *why*. Its realm does not apparently include the qualities or values of life. It investigates and appreciates only one kind of order. But besides scientific order there are also in the world aesthetic, moral and spiritual orders, all as important and valid as those of material nature, even though they may not be wholly subject to experimental sensory test and proof. And most people believe that these other values are considerably more important than those of science. But it is possible to recognize several kinds of order in any given thing. In a sunset one can recognize the functioning of certain physical laws of light, and at the same time deeply appreciate its beauty and feel its possible spiritual significance. The study of science should

not narrow or warp our apprehension of other kinds of order, but rather should enrich our inner life. This was finely expressed by the brilliant English scientist W. K. Clifford in one of his notebooks :

"Whoever has learned either a language or the bicycle can testify to the wonderful sudden step from troublesome acquirement to the mastery of new powers, whose mere exercise is delightful, while it multiplies at once the intensity and the objects of our pleasures. This I say is especially and exceptionally true of the pleasures of perception. Every time that analysis strips from nature the gilding that we prized, she is forging thereon a new picture more glorious than before, to be suddenly revealed by the advent of a new sense whereby we see it—a new creation, at sight of which the sons of God shall have cause to shout for joy.

"What now shall I say of this new-grown perception of Law, which finds the infinite in a speck of dust, and the acts of eternity in every second of time? Why, that it kills our sense of the beautiful, and takes all the romance out of nature. And moreover that it is nothing more than a combining and reorganizing of our old experiences, never can give us anything really new, must progress in the same monotonous way forever. But wait a moment. What if this combining and organizing is to become at first habitual, then organic and unconscious, so that the sense of law becomes a direct perception? Shall we not then be really seeing something new? Shall there not be a new revelation of a great and more perfect cosmos, a universe fresh born, a new heaven and a new earth? *Mors janua vitae*; by death to this world we enter upon a new life in the next. A new Elysium opens to our eager feet, through whose wide fields we shall run:

with glee, stopping only to stare with delight and to cry, "See there, how beautiful!" for the question Why? shall be very far off, and for a time shall lose its meaning."

The limitations of science and its relation to other spheres of human activity have been very clearly stated by Mr. J. W. N. Sullivan in his little book called *Gallio—or the Tyranny of Science*, published in the 'Today and Tomorrow Series' by Kegan Paul, London, 1927. Beginning at page 60 he says:

"Many people, including some scientific men, take science too seriously. They think that science gives a far more comprehensive picture of reality than it really does. There have been philosophers who have gone so far as to suppose that those factors of experience that science does not find it necessary to talk about do not really exist. This is the basis of the belief that colours, sounds and scents have no objective existence; they exist only in the mind, whereas such qualities as mass and extension are supposed to exist independently of the mind. It is true that science does not find it necessary to refer to colours, sounds and scents in giving its description of nature whereas it does find it necessary to refer to mass and extension. But that does not prove that the former qualities are not as real as the latter, are not as indubitably part of the universe. The scientific concepts have by no means proved themselves adequate to account for the whole of experience. Nearly everything of real importance to man lies at present outside science. The fact is that science was undertaken as an intellectual adventure: it was an attempt to find out how far nature could be described in mathematical terms. Certain primary conceptions—time, space, mass, force and so on—all of which

can be defined mathematically, were adopted, and it became a highly absorbing game to find out how much of what goes on around us could be described, mathematically, in terms of these conceptions. The success of this effort has been so astonishing that some scientific men have forgotten to be astonished.

"They have come to take it for granted that a complete mathematical description of the world should be possible. This assumption is not a rational one: it is a pure act of faith. The great founders of the scheme made no such mistake.

"But if we do not adopt the materialist principle we may assert that moral and aesthetic values are as much a part of the real universe as anything else, and that the reason why science does not find it necessary to mention them is not because they are not there but because science is a game played according to certain rules, and those rules have excluded those values from the outset. The life-insurance actuary may, for his purposes, neglect many things about men, and yet calculate, quite correctly, what percentage of them will die at forty. But he has not proved that the qualities he has neglected do not exist simply because they do not come in to upset his calculations. . . . In the same way, a mountain is a different thing to a poet from what it is to a man of science. For the kind of understanding of the universe that the man of science is after, the mountain is merely a heap of certain kinds of matter weighing so many millions of tons. The poet, who is after a different kind of vision, finds it necessary to take into account quite other factors which enter into his total experience of the mountain. The scientist may also experience emotions of awe and reverence in the presence of the mountain, but for the purposes of his science these factors of his experience may be neglected. He *abstracts* from the total concrete fact

of his experience of the mountain. The mountain, as he describes it in the scientific paper he proceeds to write, is a mere pale shadow of the real mountain, he probably leaves it undistinguishable from any other mountain that happens to weigh the same, just as to the life-insurance-actuary all men of forty are exactly alike. . . .

"It is the artist, not the scientist, who deals most adequately with reality. It is the man of science, taking his pale abstractions for the only realities, who dwells in dreamland. . . .

"Science, in view of our increased knowledge of its aims and powers, can no longer be presented to us as a tyrant. Science assumes certain fundamental principles and entities, and there is an arbitrary element in these assumptions. What science does not assume does not thereby not exist. It gives, and it appears that it must forever give, a *partial* description of the universe. The fact that the elements of reality it leaves out do not come in to disturb it is no presumption against the existence of those elements. For science forms a closed system simply because it employs the device of cyclic definition (*i. e.*, the entities discussed by it are defined in terms of one another). The teachings of science, so far as the spiritual problems of men are concerned, need no longer be regarded as stultifying; they are merely irrelevant."

In an interview published in the *Evening Transcript* (Boston, Mass., U. S. A.) for June 2, 1928, Prof. J. A. Thomson of Aberdeen University speaks about this aspect of science as follows :

"I regard science as a very partial way of getting at reality. In science we are like people fishing in the sea with a particular kind of net with a particular kind of

mesh; but there are fish in the sea that we cannot get with that kind of net and that kind of mesh. So I recoil from the rather self-satisfied, dogmatic, scientific position associated with scientific positivism, because of my conviction that by feeling, by enjoyment, and by a sort of practical co-operation, we can get at things that cannot be reached by science. For instance, one gets very much attached to a countryside, and this love of the country, which is one of the greatest gains a man can have, that is due in part to the knowledge of beasts and birds, trees and flowers no doubt attained along scientific lines, is also reached in part by daily enjoyment of the country's beauty and mystery. To me what one gets through the appreciation of beauty is just as real as what one gets through, say, geology. To put it more tersely, there are various rights of way to reality. One is by the use of the scientific method. But I plead, as against the scientific positivists, that there is another right of way—through feeling, sympathy, and practical working with things."

The great poet Rabindranath Tagore comments briefly on this topic in his book *Personality* (Macmillan, London, 1923) at pages 52 and 90. He says :

"Our scientific world is a world of reasoning. It has its greatness and uses and attractions. We are ready to pay the homage due to it. But when it claims to have discovered the real world for us and laughs at the worlds of all simple-minded men, then we must say it is like a general grown intoxicated with his power, usurping the throne of his king. For the reality of the world belongs to the personality of man and not to reasoning, which, useful and great though it be, is not the man himself. . . .

"Science has a materialistic appearance, because she is engaged in breaking the prison of matter and working in the rubbish heap of the ruins."

The concepts of *Dharma* and *Karma* furnish examples of moral and spiritual order and law which are entirely familiar to the Hindu boy, and the Koran and Zoroastrian and Buddhist ethics supply other examples for boys of other faiths in India. If in our teaching we take care to have the boys understand the presence and importance of all kinds of order, and do not unduly stress the material order, there should be no grave danger of their failing to see and live life in right proportion, so far as science is concerned.

In this connection it will perhaps be well to bear in mind the warning of the distinguished English mathematician, Mr. Bertrand Russell:

"A science may affect human life in two different ways. On the one hand, without altering men's passions or their general outlook, it may increase their power of gratifying their desires. On the other, it may operate through an effect upon the imaginative conception of the world, the theology or philosophy which is accepted in practice by energetic men. . . . Science has not given men more self-control, more kindness, or more power of discounting their passions in deciding upon a course of action. It has given communities more power to indulge their collective passions, but by making society more organic, it has diminished the part played by private passions. Men's collective passions are mainly bad; far the strongest of them are hatred and rivalry directed

toward other groups. Therefore at present all that gives men power to indulge their collective passions is bad. "That is why science threatens to cause the destruction of our civilization." *

Mr. Russell is pessimistic about science really not because it is bad but because in Europe it is not properly balanced by religious and moral and aesthetic order. An excess of anything is bad. If a man takes a very great amount of water and too little food and air, it is very bad for him. But to say therefore that water is bad would not be true. What is bad is an excess of anything and a deficiency of other things which are necessary to life. The problem is not one of exclusion, but of securing right proportion. It is a question of right use. European life is at present unbalanced. I believe that India may help correct and restore the balance. But India, too, is not wholly balanced at present, and perhaps a wise use of science may help restore her national vigour.

On this point Tagore says, in his *Creative Unity* (Macmillan, New York, 1922), page 108:

" . . . The East must find her own balance in Science — the magnificent gift that the West can bring to her. Truth has its nest as well as its sky. That nest is definite in structure, accurate in law of construction; and

*From his article, 'The Effect of Science on Social Institutions' in *The Survey Graphic* for April, 1924, New York. See also his booklet, *Icarus, or the Future of Science*, Kegan Paul, London, 1925.

though it has to be changed and rebuilt over and over again, the need of it is never-ending and its laws are eternal. For some centuries the East has neglected the nest-building of truth. She has not been attentive to learn its secret. Trying to cross the trackless infinite, the East has relied solely upon her wings. She has spurned the earth, till, buffeted by storms, her wings are hurt and she is tired, sorely needing help."

Here it may be remarked, parenthetically, that this gift of science from West to East should be rendered not with any sense of superiority or complacent pride on the part of the West, but only in great humility. For in truth it is an inadequate payment of a long-deferred debt, a slight rendering account of a stewardship, a slender return from a pupil to his master. The reasons are there.

Modern science never could have come into existence without the aid and means of instruments of great precision. Such instruments could be made only by modern machines. The development of modern machinery came, and could only come, after the invention of the steam engine and the manifold uses of physical power and technology evolved in Western industrialism. This development of power-driven machinery and technology arose in England and first flowered there. This vast development of machinery required great amounts of liquid capital. It is well recognized by historians that the source from which England suddenly obtained,

this capital at that time was the gold and other treasure which the East India Company and its assistants and followers took from India.

Hence, the energy represented by all that treasure, the symbol of the accumulated results of the labour of millions of people for many centuries, was transferred from East to West, and there part of it has been transmuted into scientific knowledge and method.

If now some of that energy or stimulus comes back to India in this new form, to help her regain her former position, let not the West indulge in vanity or condescension, but rather be thankful for the opportunity to share in brotherly humanity. And India may, in this sense, be ready to accept science not as an alien thing or with suspicion, but as a regaining of part of her rightful heritage. This seems to apply to China also.

And there are further reasons for humility from the West in this matter. Such a bringing of science to the East is in no sense a restoration of what has been taken from her. That could only be approached if the return were in kind and equal in utility, in money value and in aesthetic and ethical value to what was taken. Moreover, the West needs to remember that two of the greatest of all inventions came from Asia, — printing from China and the spinning wheel from India. The latter has made possible the

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clothing of practically the entire human race, and the former is the basis of the spread of all modern knowledge. Of course science and invention are not synonymous, but invention rests upon observation, comparison, deductive reasoning, and experiment,—all of them included in scientific method. Much agricultural and other knowledge also comes from Asia. And mathematics, the science of sciences, is indebted to the Hindus for the so-called Arabic numeration, for much algebra, and some geometry. Astronomy, medicine, chemistry and other sciences progressed far in India before they reached even an elementary stage in Europe. It is also to be remembered that Indians have never used their inventions or science to kill or exploit peoples of other nations. This cannot be said of Europe or America. Let the West, as the pupil of Asia, learn to practise the grace of a just humility.

Exercise XXXI attempts to affect any tendency of the study of science to spoil the boys' appreciation of the true values of ancient Indian craftsmanship and agriculture.

3. Why Prepare?

Now to the question whether a *preparation* for science is needed.

In Mr. Benchara Branford's *A study of Mathematical Education* (Oxford University

Press, London, 1921), we find the following passages :

(p. 47) "I shall make use of the fundamental principle—namely, the parallelism between the development of the individual and that of the race. I think we might almost say that that has become one of the most important and central principles of education. . . ."

"We can practically take it now as established by a large number of lines of evidence coming through many sciences, that the individual does recapitulate in his own development the essential lines through which the race has passed—I say the essential lines, not the details. It is, I believe, admitted by experts to be true biologically: it was first found in biology: and now it is seen to be true also for the mental or psychic organization. Of course we have to remember that there are a great many limitations to the principle: there are such things as short cuts, compressions and modifications, both in the biological development and in the psychic development, but the essential truth of the position is now established beyond serious attack. . . ."

(p. 244) "The path of most effective development of knowledge and power in the individual coincides, in broad outline, with the path historically traversed by the race in developing that particular kind of knowledge and power."

We find that in Europe, where modern science developed, there was a slow growth of certain ideas and attitudes of mind before the age of science actually flowered. This is very interestingly shown in the following quotation from a chapter on 'Language and Thought' in a book entitled *The English Language* by Logan:

Pearsall Smith, M. A. I did not come across this passage until after I had developed my ideas as to the necessity for preparing the minds of the boys for science. The facts stated in this extract, together with the principle stated above by Mr. Branford seem to me to support very strongly the need of what I advocate. I therefore quote at some length:

"It is a commonplace to say that the dominant conception of modern times is that of science, of immutable law and order in the material universe. This great and fruitful conception so permeates our thought, and so deeply influences even those who most oppose it, that it is difficult to realize the mental consciousness of a time when it hardly existed. But if we study the vocabulary of science, the words by which its fundamental thoughts are expressed, we shall find that the greater part of them are not to be found in the English language a few centuries ago; or if they did exist, that they were used for religious institutions or human affairs; and that their transference to natural phenomena has been very gradual and late. *Order* is, indeed, a very old word in English, and appears in the 13th century in reference to monastic orders, and the heavenly hierarchy, Thrones, Dominations, Powers, etc. of Christian theology. It acquires some notion of fixed arrangement in the 14th century, but it is not till the 16th century that its derivatives *orderliness* and *orderly* are found. *Ordered* meant in holy orders till this period, when we also find the noun *disorder*. *Regular* is a 14th century word, but it was also used of monastic orders (being the opposite of *secular*) until 1584; while *regularity*, *regulation*, and the verb *to regulate* belong to the following century.

Method and *system* are also modern words, with the adjectives *methodical*, *systematic* and *uniform*. The verb *to arrange* is an old word, and was used like *array* in a military sense; but it does not appear in Shakespeare or the Bible, and did not acquire its present meaning until the 18th century, at which time *arrangement* is also found. The verb *to classify*, with *classification*, belongs to the 18th century; *organism* to the 17th, at which time the slightly earlier *organize* and *organization* acquired their present meanings.

"If we take the great word *law*, we do not find it applied in English to natural phenomena before the Restoration, although its Latin equivalent *lex* was employed in this sense by Bacon earlier in the 17th century. The Roman and mediæval phrase *natural law* (*lex naturæ* or *naturalis*) meant the law of God implanted in the human reason for the guidance of human conduct; and even the *laws of nature*, by those who first used the phrase in our modern sense, were, as the Oxford Dictionary tells us, regarded as commands which were imposed by the Deity upon matter, and which, as we still say, were obeyed by phenomena.

"Many other instances could be given, but the above will suffice to show how the notion of law and order in nature and visible phenomena spread in the 16th and 17th centuries, replacing the older notions of magic or divine interference. Partly produced by this sense of law and order in nature, and probably still more the cause of it, we notice also at this time a great increase in the vocabulary of observation. Speaking generally, we find that the names of the abstract reasoning processes — *reason*, *cognition*, *intuition*, etc. — belong to the Middle Ages, while those which describe the investigation of natural phenomena belong to the modern epoch, or only acquire.

at that time; their present meaning and their popular use. *To observe* meant to obey a rule, or to inspect auguries for the purpose of divination, until the 16th century, when it acquired the meaning of examination of phenomena; *observant* and *observation* were old religious words meaning the obedience to religious laws, until the same time; *perception* meant the collection of rents till the 17th century, and *scrutiny* was only used of votes until that period. *Experiment* and *experimental* are old words used in alchemy, but experiment as a process (as in the phrase *to try by experiment*) is modern, and *experimental* had hardly more than the vague meaning of 'observed' until the 16th century. The verbs *to analyze*, *to distinguish*, *to investigate*, appear in the same period, and in the next hundred years *to remark*, *to inspect*, *to scrutinize*; *to notice* is an old verb meaning *to notify*, but it fell out of use and was only revived and given its present meaning in America at about the middle of the 18th century. We may also note that while words expressing belief—*certainty*, *assurance*, *credence*, etc.—are generally old in the language, those that suggest doubt, questioning and criticism, almost all belong to the modern period. *Doubt* is, of course, an old theological word, and *doubtful* appears in the 14th century; but *doubtfulness*, *dubious*, *dubiousness*, *dubitable*, with *sceptic*, *sceptical*, *scepticism*, are of modern formation; and in this period, too, the old verbs *to dissent* and *disagree* became applied to matters of conviction.

"This conception of order in the material universe and the spirit of investigational inquiry resulted, of course, in a great increase of knowledge about natural phenomena. This increase of knowledge, and its popular diffusion, shows itself very clearly in the large number of words that now come into use to describe the qualities of matter.

We note in the 16th century a new use of words like *tenacity* and *texture*, while in the following century we find *cohesion*, *tension*, *elasticity* and *temperature*. At the same time, too, the word *force* acquired its physical meaning; and *energy*, a word of Aristotle's creation, which was first employed in English as a term of literary criticism, was applied to the material world, although its precise modern use was not defined before the 19th century.

"But this conception of science was not so much a new discovery as the revival of ancient thought which found, at the renaissance, an atmosphere favourable to its fruitful development. The order, however, which the ancients found in the universe was a fixed and unchangeable one; the belief in progressive change, in evolution, is modern, and forms perhaps the most essential difference between our view of the world and that of the Greeks and the Romans. We do not, perhaps, always realize how very modern the conception is, but if we take the words by which it is expressed—*advance*, *amelioration*, *development*, *improvement*, *progress*, *evolution*, we shall find that none of them can be found in English with their present meaning before the 16th century. *Advance* and *advancement* are old words in English, with the meaning of promotion from a lower to a higher office; and only acquire the sense of progress after the Middle Ages. *Improve* and *improvement* were terms of Law French, originally applied to describe the process of enclosing waste land and bringing it into cultivation; they acquire the sense of 'making better' in the 17th century, and one of the earliest uses of 'improved,' with this modern meaning is found, appropriately enough, in the title of 'The Royal Society of London for improving Natural Knowledge' founded about 1660.

"*Evolution* is of course, a modern word in English; it appeared first in a military sense in the 17th century, and acquired its present meaning and its immense development from the work of Darwin and Herbert Spencer in the 19th century. . . .

"*Progress* is an old word for a journey, 'a royal progress;' it began to acquire the meaning of continuous improvement in the time of Shakespeare, which time the verb *to progress* appeared, and the adjective *progressive* which was used by Bacon in his essays. The verb, however, became obsolete in English, and was introduced again from America after the notion of progress, taken into their systems and popularized by the 18th century philosophers, had found its way into the popular imagination, and had given birth to the great new hope of modern times, the modern belief that human society is advancing, or can advance, to better and better conditions."

That there was a long period of development of preliminary ideas before modern science came into being is recognised by the distinguished mathematician and philosopher, A. N. Whitehead. In his book *Science and the Modern World* (Cambridge University Press, 1927), in the chapter on 'The Origins of Modern Science,' he shows that before science developed in Europe there grew up an instinctive sense of law and order based probably on the concept of a personal, responsible, causative God; and a general interest in Nature and the objective world, during the Renaissance. These ideas and attitudes were a part of what he calls the general 'mental

climate' of that continent and period of history. Also the spirit of curiosity, wonder, adventure and search was abroad, stimulated greatly by the discoveries of navigators like Columbus. He says :

.. "In the first place there can be no living science unless there is a widespread instinctive conviction in the existence of an *Order of Things*, and, in particular, of an *Order of Nature*. . . . But until the close of the Middle Ages the general educated public did not feel that intimate conviction, and that detailed interest, in such an idea, so as to lead to an increased supply of men, with ability and opportunity adequate to maintain a coordinated search for the discovery of these hypothetical principles. . . . The Middle Ages formed one long training of the intellect of Western Europe in the sense of order."

We may safely say that in certain respects in regard to his mode of living and his attitude toward the world and Nature the Indian village boy is in much the same intellectual position as the European of the Middle Ages. If so, and if he is to learn modern science, he must go through a period of preparation to enable him to grasp and assimilate the attitudes, concepts and ways of thinking which lie at the basis of science.

4. *The Necessity for Systematic Sensory Exercise and Experience*

I have said that such exercises and drill should be largely based on sensory experience, on manipulation; and that the results aimed at should be largely unconscious. That is, there:

should be no attempt to secure vocal or written expression, description or explanation from the pupils of what they have done or learned.

In support of this procedure let me cite once more Shri Aurobindo Ghose and Mr. Benchara Branford. The former, in his essay on *A System of National Education** says:

(p. 9) "It is the first business of the educationist to develop in the child the right use of the six senses; to see that they are not stunted or injured by disease, but trained by the child himself under the teacher's direction to that perfect accuracy and keen subtle sensitiveness of which they are capable. In addition, whatever assistance can be gained by the organs of action should be thoroughly employed. The hand, for instance, should be trained to reproduce what the eye sees and the mind senses. . . .

(p. 42) "It is also very desirable that the hand should be capable of coming to the help of the eye in dealing with the multitudinous objects of its activity so as to ensure accuracy. This is of a use so obvious and imperatively needed, that it need not be dwelt on at length. The practice of imitation by the hand of the thing seen is of use both in detecting the lapses and inaccuracies of the mind in noticing the objects of sense, and in registering accurately what has been seen. Imitation by the hand ensures accuracy of observation. This is one of the first uses of drawing and it is sufficient in itself to make the teaching of this subject a necessary part of the training of the organs.

(p. 43 to 46) "The first qualities of the mind that have to be developed are those which can be grouped under observation. . . . Full concentration of the

Faculty of observation gives us all the knowledge that the three chief senses can gather about the object, or if we touch or taste, we may gather all that the five senses can tell us of its nature and properties. Those who make use of the six senses, the poet, the painter, the Yogin, can also gather much that is hidden from the ordinary observer.

The scientist by investigation ascertains other facts open to a minutest investigation. These are the components of the faculty of observation, and it is obvious that its basis is attention, which may be only close or close and minute. . . . The first thing the teacher has to do is to accustom the pupil to concentrate attention.

"We may take the instance of a flower. Instead of looking casually at it and getting a casual impression of scent, form and colour, he should be encouraged to know the flower—to fix in his mind the exact shade, the peculiar glow, the precise intensity of the scent, the beauty of curve and design in the form. His touch should assure itself of the texture and its peculiarities. Next, the flower should be taken to pieces and its structure examined with the same carefulness of observation. All this should be done not as a task, but as an object of interest by skilfully arranged questions suited to the learner which will draw him on to observe and investigate one thing after the other until he has almost unconsciously mastered the whole.

"A similar but different flower should be put in his hands and he should be encouraged to note it with the same care, but with the avowed object of noting the similarities and differences. By this practice daily repeated the memory will naturally be trained. Not only so, but the mental centres of comparison and contrast will begin to observe as a habit the similarities of things and their differences. The teacher should take every care to

encourage the perfect growth of this faculty and habit. At the same time the laws of species and genus will begin to dawn on the mind, and by a skilful following and leading of the young developing mind; the scientific habit, the scientific attitude and the fundamental facts of scientific knowledge may in a very short time be made a part of its permanent equipment."

Branford, in his book above cited, quotes the famous German scientist Ernest Mach and the English mathematician Boole as follows:

"I know of nothing more terrible than the poor creatures who have learned too much. Instead of that sound, powerful judgment which would probably have grown up if they had learned nothing, their thought creeps timidly and hypocritically after words, principles and formulae constantly by the same paths. What they have acquired is a spider's web, too weak to furnish sure supports, but complicated enough to produce confusion" (Mach).

"Of the many forms of false culture, a premature converse with abstractions is, perhaps, the most likely to prove fatal to the growth of a masculine vigour of intellect" (Boole).

On the value of sub-conscious sensory experience Branford has spoken with such wisdom that he compels fairly extensive quotation at this point. The following passages are especially pertinent:

"(p 53) . . . This is a fact I would very much like to impress upon all teachers, the deep importance of this sub-conscious life without language at all."

"(p. 71) It is well established that every thought we have, every feeling we have, every internal mental state, is accompanied by a certain amount of muscular activity, either voluntary or involuntary, conscious or unconscious, but mostly unconscious."

"(pp. 120-121) Most thinking is done without language. This applies to the painter, sculptor, musician, experimenter, all artists and craftsmen and above all to the child, and the more so the younger he is. The external expression of the thought (its own contents based as above stated on sensation and feeling) may or may not be verbal: if verbal, then a distinct scientific or literary discovery, communicable to others with like experience, has been made. The discovery, of course, may be great or small. Now it is one of the functions of the teacher to stimulate the pupil to a development into verbal or literary expression of his subconscious and conscious experience, and language itself is the teacher's most effective instrument thereto. But this very fact implies that the experience must be there first, or it cannot be developed into self-expression either verbally, or non-verbally (as in designing, geometrical drawing, etc.). The fit place of the verbal expression is as the summit and crown of the experimental process. Science and literature in individual and race follow sensuous experience as its verbal expression: to place the language (definition, etc.) first is to reverse the natural order by artificial authority of the teacher, and results in mere rote work, lack of interest, and suppression of initiation and originality; it is, indeed, to give the symbol without the experience symbolized.

"The teacher cannot realize too clearly the profound truth that the substance, contents, matter (call it what one will) of ideas can never be created in the pupil's mind by mere spoken words, however carefully chosen.

The spoken word is in itself nothing but so much sound unless the substance, matter, contents of the idea, symbolized by the word, already exists in the pupil's mind as a subconscious product created by previous physiological stimulation which resulted in sense impressions. If this experience, lying latent or subconscious, is there, then the function of the spoken word is to raise this subconscious product to the level of the consciousness. Thus the pupil becomes conscious of his own stores of experience, is assisted to create new mental connections, to strengthen old ones, and in short to systematize his experience into a conscious tool available for his own further development. The substance of ideas, as such, is therefore not communicable from one mind to another. In speaking to others, the condition that our words be intelligible is a reasonable degree of similarity: the less the similarity, the less our intelligibility, until in extreme (and too frequent) cases the dissimilarity of experience is so great that there is complete misunderstanding between pupil and teacher, and rote work is the inevitable result.

" . . . In the summing up of a piece of sensuous experience, language succeeds to sense experience. But the newly gained language in its turn serves to sharpen the senses to discover new aspects of concrete things, otherwise blindly overlooked, and therefore such language now precedes the discovery of new sensuous experience: but this again simultaneously classifies and deepens the significance of the previous language, and demands new language for its own expression and summing up. . . .

" . . . The order is, then, not a mere simple passage from sense to thought, from concrete to abstract . . . but a spiral of progress in which each new group of sense-impressions leads to the creation of a new

concept . . . and in which each new concept thus gained is (consciously or unconsciously) applied to the development of new sense-impressions. The two processes lead to fuller and fuller interpretation of the world around, and deepening significance of language itself. . . . Kant may be appropriated to sum up the two aspects, neither of which any teacher can neglect with any impunity: 'the senses without thought are blind: thought without the senses is empty.'

"(p. 241) The best path to be followed by the pupil is clearly *through the experimental and intuitional stages toward the scientific stage*: what the race has never been able to accomplish, it is unsound to expect of the child, boy and girl."

"(pp. 294-295) As ideas are built upon sensations, if you fail to supply a wealth of material for sensation, *e.g.*, with counters, bricks, paper-folding, practical surveying and mensuration, geometrical drawing, and so on,—but few *ideas* will get formed at all, the inner mental life of connected thoughts will be scanty, and consequently vividness and interest will be lacking. 'Concepts or ideas are mere empty words in any mind in which they do not awaken a large group of well-ordered sensations or sense-impressions.'

"(p. 303) Long and thoroughly practised *actions* are thus the very kernel of concepts. In fact, positive and philosophical philology both claim to have established that all roots represent concepts and *stood originally for muscular activities alone*.

"Again, the 'general' or 'abstract' is not a content at all, says Professor Baldwin. It is an attitude, an expectation, a motor-tendency. It is the possibility of a reaction which will answer equally for a great many particular experiences."

Although these words describe the foundation, they do not give the whole edifice of a concept. Perhaps we may usefully here quote Prof. Aliotta in his *Idealistic Reaction against Science* (Macmillan, London, 1914). He says at pages 402-3 :

"The scientific concept is something more than a mere summary of perceptions; it is not an *abridged* experience, but an idealized experience, and its fruitfulness lies in its ideal character. In respect to experience, it is not an impoverishment but a raising of it to a higher power; it is experience purified and carried to its ideal limit in order that it may satisfy the demands of necessity and logical universality. . . . Every scientific concept is therefore in itself an anticipation of the future; the stamp of universality imprinted upon it by thought impels it to transcend past experience and foresee the future. For thought does not rest content with merely making a more or less economical record of perceptions, but seeks its own ideal nature in those perceptions, creating concepts which correspond more and more nearly to that type of unity which is its supreme law. . . ."

The poet and educationist Tagore, apparently agrees with this emphasis upon the importance of the subconscious mind in education. In his book entitled *Personality* (Macmillan, London, 1923, Indian Edition) at page 139 he says :

"I believe, as I suggested before, that children have their subconscious mind more active than their conscious intelligence. A vast quantity of the most important of our lessons has been taught to us through this. . . ."

"This subconscious faculty of knowledge is completely one with our life."

Thus my conclusions seemed to be amply substantiated by many authoritative educationists and thinkers. At this point I happily came upon an original-minded teacher who had gathered the essence of these ideas together into a practical method of training and teaching. This gave me the start for what I have developed in the later pages of this book. This man was Charles H. Hinton, and the book in which he sets forth many of his ideas is called *A New Era of Thought* (published by Geo. Allen Unwin, London, 1910). Let me quote from him. On pages 15 to 25 of this book he says, in part:

"In the course of my experience as a teacher I have often been struck by the want of power of reason displayed by pupils; they are not able to put two and two together, as the saying goes, and I have been at some pains to investigate wherein this curious deficiency lies, and how it can be supplied. And I have found that there is in the curriculum no direct cure for it, . . . the discipline which supplies it is not one which comes into school methods, it is a something which most children obtain in the natural and unsupervised education of their first contact with the world, and lies before any recognized mode of distinction. They can only understand in virtue of an activity of their own, and they have not had sufficient exercise in this activity. . . .

"I have seen that the same activity, which, I have found, makes that habit of mind which we call intelligence in a child, is the source of our common and every day

rational intellectual work, and that just as the faculties of a child can be called forth by it, so also the powers of a man are best prepared by the same means, but on an ampler scale. . . .

"In order to tell what the activity is, by the prosecution of which we can obtain mental contact with nature, we should observe what it is which, we say, we 'understand' in any phenomenon of nature which has become clear to us.

"When we look at a bright object it seems very different from a dull one. A piece of bright steel hardly looks like the same substance as a piece of dull steel. But the difference of appearance in the two is easily accounted for by the different nature of the surface in the two cases; in the one all the irregularities are done away with, and the rays of light which fall on it are sent off again without being dispersed and broken up. In the case of the dull iron, the rays of light are broken up and divided, so that they are not transmitted with intensity in any one direction, but flung off in all sorts of directions..

"Here the difference between the bright object and the dull object lies in the arrangement of the particles on its surface and their influence on the rays of light.

"Again, with light itself the differences of colour are explained as being the effect on us of rays of different rates of vibration. Now a vibration is essentially this, a series of arrangements of matter which follow each other in a closed order, so that when the set has been run through, the first arrangement follows again. The whole theory of light is an account of arrangements of the particles in the transmitting medium, only the arrangements alter—are not permanent in any one characteristic, but go through a complete cycle of varieties.

“Again, when the movements of the heavenly bodies are deduced from the theory of universal gravitation, what we primarily do is to take account of arrangement; for the law of gravity connects the movements which the attracted bodies tend to make with their distances, that is, it shows how their movements depend on their arrangement. And if gravity as a force is to be explained itself, the suppositions which have been put forward resolve it into the effect of the movements of small bodies; that is to say, gravity, if explained at all, is explained as the result of the arrangement and altering arrangements of small particles. [The author was writing in the year 1910. But it is interesting to note that Einstein’s explanation of gravitation, being geometrical, is a matter of arrangement, in a large aspect. R. B. G.]

“Again, to take the idea which proceeding from Goethe casts such an influence on botanical observation. Goethe (and also Wolf) laid down that the parts of a flower were modified leaves, and traced the stages and intermediate states between the ordinary green leaf and the most gorgeous petal or stamen or carpel, so unlike a leaf in form and function.

“Now the essential value in this conception is, that it enables us to look upon these different organs of a plant as modifications of one and the same organ—it enables us to think about the different varieties of the flower head as modifications of one single plant form. We can trace correspondences between them, and are led to possible explanations of their growth. And all this is done by getting rid of pistil and stamen as separate entities, looking on them as leaves, and their parts due to different arrangements of the leaf structure. We have reduced these diverse objects to a common element, we have found the unit by whose arrangements the whole is produced. And in this department of thought, as also to take another

instance, in chemistry, to understand is practically this: we find units (leaves or atoms) combinations of which account for the results which we see. Thus we see that that which the mind essentially apprehends is arrangement.

"And this holds over the whole range of mental work, from the simplest observation to the most complex theory. When the eye takes in the form of an external object there is something more than a sense impression; something more than a sensation of greenness and light and dark. The mind works as well as the sense, and these sense-impressions are definitely grouped in what we call the shape of the object. The essential act of *perceiving* lies in the apprehension of a shape, and a shape is an arrangement of parts. It does not matter what these parts are; if we take meaningless dots of colour and arrange them we obtain a shape which represents the appearance of a stone or a leaf to a certain degree. If we want to make our representation still more like, we must treat each of the dots as in themselves arrangements, we must compose each of them by many strokes and dots of the brush. But even in this case we have not got anything else besides arrangement. The ultimate element, the small items of light and shade or of colour, are in themselves meaningless; it is in their arrangement that the likeness of the representation consists.

"Thus, from a drawing to our notion of the planetary system, all our contact with nature lies in this, in an appreciation of arrangement.

"Hence, to prepare ourselves for the understanding of nature, we must 'arrange.' In virtue of our activity in making arrangements we prepare ourselves to do what is called understand nature. Or we may say, that which we call understanding nature is to discern something similar in nature to that which we do when we arrange elements into compounded groups.

"Now if we study arrangement in this active way, we must have something to arrange; and the things we work with may be either all alike, or each of them varying from every other.

"If the elements are not alike then we are not studying pure arrangement; but our knowledge is affected by the compound nature of that with which we deal. If the elements are all alike, we have what we call units. Hence the discipline preparatory for the understanding of nature is the active arrangement of like units.

"And this is very much the case with all educational processes; only the things chosen to arrange, are, in general, words, which are so complicated and carry such a train of association, that unless the mind has already acquired a knowledge of arrangement, it is puzzled and hampered, and never gets a clear apprehension of what its work is.

"Now what shall we choose for our units? Any unit would do; but it ought to be a real thing—it ought to be something which can be touched and seen, not something which no one has ever touched or seen, and which is even incapable of definition, like a 'number.'

"I would divide studies into two classes: those which create the faculty of arrangement, and those which use it and exercise it. Mathematics exercises it, but I do not think it creates it; and unfortunately, in mathematics as it is now often taught, the pupil is launched into a vast system of symbols—the whole use and meaning of symbols (namely, as means to acquire a clear grasp of facts) is lost to him.

"Of the possible units which will serve, I take the cube; and I have found that whenever I took any other unit I got wrong, puzzled and lost my way. With the cube one does not get along very fast, but everything is

perfectly obvious and simple, and builds up into a whole of which every part is evident. . . .

"Our work will then be this: a study, by means of cubes, of the facts of arrangement. And the process of learning will be an active one of actually putting up the cubes. In this way we do for the mind what Wordsworth does with the imagination,—we bring it into contact with nature."

All the rest of Mr. Hinton's book is devoted to the use of this method as a possible means of apprehending figures in four-dimensional space, and need not concern us further. But the idea above set forth lies behind all the exercises which I developed and have explained in the latter part of this booklet. I know only in a very general way about Madame Montessori's work and theory and the exercises which she has developed for children, but in a sense the foregoing exercises are perhaps a little like hers, though with a more limited and different scope and purpose.

The fact that most Indian young men who have studied science in India seem to be so lacking in originality, initiative and creativeness in that field (N. B. the small amount of scientific research work in relation to the size of the universities), may well be due partly to their lack of sufficient sensory foundation for the abstract ideas which they have to cram into their heads. Having to learn so much of their science in a language not their own is another

very severe handicap and drag on their mental powers. This is not said by way of condemnation, but in regret at the waste and futility of so much effort and good intention and minds originally and intrinsically keen and alert. The fault is with the educational system,—not with the pupils or even with the teachers. It is a vicious circle very hard to break. Possibly the method herein proposed may help a little to mitigate part of the evil at the start.

5. *What is Science?*

Inasmuch as the exercises hereinafter given are only by way of suggestions, and it is hoped that they will be modified and developed by the teachers, it will perhaps be helpful, as a guide to them in their selection and adaptation of the experiments, briefly to indicate what science really is and what it is not. It is not easy for Indian village teachers to procure expensive books which explain the most recent thoughts of scientists about their subject. There has been far more confusion about this matter than one would suppose. Also the recent developments of science and mathematics have illuminated the problem very much.

A few quotations from leading scientists and educationists will be the only sound way to answer this question, although this reveals me as only a dealer in second-hand thoughts.

Mr. J. A. Thompson thus defines science, at page 1165 of volume IV of his *Outlines of Science* (G. P. Putnam's Sons, London):

"The establishment of a science depends on processes of selection and detachment, what might be called isolating certain aspects of things. . . . Science begins, when, from a great number of experiences, one general conception is formed which will embrace all similar cases. Science means unifying diversities and detecting uniformities. . . . We explain an event not when we know *why* it happened, but when we know *how* it is like something else happening elsewhere—when in fact we can include it as a case described by some law already set forth. . . . A law resumes, in a few brief words, the relationships observed between a vast range of phenomena. . . . Science aims at the formulation of things as they are and as they have come to be. . . .

"The scientific mood . . . is marked by (1) a passion for facts (this includes a high standard of accuracy and a detachment from personal wishes); (2) a cautious thoroughness in coming to a conclusion (this implies a persistent scepticism and self-elimination in judgment); (3) a quality of clearness (which includes a dislike of obscurities, ambiguities, and loose ends); and (4) a less readily definable sense of the inter-relations of things, an insight which discerns that apparently isolated phenomena are integral parts of a system. . . .

"THE METHODS OF SCIENCE

"In any scientific inquiry the first step is to get at the facts, and this requires precision, patience, impartiality, watchfulness against the illusions of the senses and the mind, and carefulness to keep inferences from mingling with observations. The second step is accurate registration of the data. In most cases science begins with measurement,

. . . A third step is arranging the data in workable form—a simple illustration being a plotted-out curve which shows at a glance the general outcome of a multitude of measurements. . . . The data may have to be expressed in their simplest terms reduced perhaps to a common denominator with other sets of facts with which they have to be compared. . . . The fourth step is when a whole series of occurrences is seen to have a uniformity, which is called their law.

“The Laws of Nature are men’s descriptive formulae of uniformities of sequence, which enable him to say, if this, then that. . . . The various sciences differ greatly in their degree of precision. . . . Science is a system of knowledge built upon a basis of observation and experiment, and compacted by reflection on the data thus supplied.”

Mr. Benchara Branford, in his other book, *Janus and Vesta* (Chatto & Windus, London, 1916), describes science thus:

“(p. 160) Science is knowledge of form, Truth is knowledge of spirit.”

“(p. 185) Science is born anew in that wonderful world within each man when with deliberate will he succeeds in thinking about the principles of his work in the great world without in a clear, logical and systematic way, and courageously puts his conclusions to the test of experiment; and the so-called sciences are the written records of such thinking, only more extensive, clear, systematic and consistent, and more true to reality because they have been tested by countless experiments and experiences in the race.”

“(p. 215) Our vaunted scientific explanations of the Universe are but working models of bounded and

selected domains, thinking machines to economize thought, conceptual shorthand resumes of a finite experience."

Professor G. N. Lewis, in his *Anatomy of Science* (Yale University Press, New Haven, U. S. A., 1926) at page 193 says,

"We might define science as the search for relationships between all sorts of existing phenomena."

And elsewhere he remarks:

"I have no patience with attempts to identify science with measurement, which is but one of its tools, or with any definition of the scientist which would exclude a Darwin, a Pasteur or a Kekule."

In a very fine essay *On the Aims and Instruments of Scientific Thought* (Watts & Co., London), W. K. Clifford said:

"Scientific thought does not mean thought about scientific subjects with long names. There are no scientific subjects. The subject of science is the human universe; that is to say, everything that is, or has been, or may be related to man.

"Now it seems to me that the difference between scientific and merely technical thought. . . . is just this: Both of them make use of experience to direct human action; but while technical thought or skill enables a man to deal with the same circumstances that he has met with before, scientific thought enables him to deal with different circumstances that he has never met with before. . . .

"The step, then, from past experience to new circumstances must be made in accordance with an observed uniformity in the order of events. This uniformity has held good in the past in certain places; if it should also hold good in the future and in other places,

then, being combined with our experience of the past, it enables us to predict the future, and to know what is going on elsewhere; so that we are able to regulate our conduct in accordance with this knowledge.

"The aim of scientific thought, then, is to apply past experience to new circumstances; the instrument is an observed uniformity in the course of events. By the use of this instrument it gives us information transcending our experience, it enables us to infer things that we have not seen from things that we have seen; and the evidence for the truth of that information depends on our supposing that the uniformity holds good beyond our experience.

"I say that a law is practically universal which is more exact than experiment for all cases that might be got at by such experiments as we can make. We assume this kind of universality, and we find that it pays us to assume it. But a law would be theoretically universal if it were true of all cases whatever; and this is what we do not know of any law at all. . . .

"When we say that the uniformity which we observe in the course of events is exact and universal, we mean no more than this: that we are able to state general rules which are far more exact than direct experiment, and which apply to all cases that we are at present likely to come across.

"By scientific thought we mean the application of past experience to new circumstances by means of an observed order of events. By saying that this order of events is exact we mean that it is exact enough to correct experiments by, but we do not mean that it is theoretically or absolutely exact, because we do not know. The process of inference we found to be in itself an assumption of uniformity, and we found, that as the known exactness of the uniformity became greater, the stringency of the inference increased."

J. W. N. Sullivan, in his *Gallio* above referred to, says,

"All that depends on the *structure* of reality belongs to physics, including other universes than ours. All that depends upon the *substance* of reality forever lies outside physics."

In an article called 'Is Science a Blind Alley?' by James Truslow Adams, in Harper's Magazine (New York) for February, 1928, there is this passage:

"Poincare, the leading mathematician and one of the leading scientists of our time, has admitted that science can teach us nothing of the real nature of things, that all it can do, and that only in part, is to elucidate certain relations between them. Moreover, as he explains, science deals with only a very limited number of facts, those which recur with sufficient frequency to enable us to establish 'laws', which, as another scientist says, are 'hypotheses with a high degree of probability.' As Poincare says again, we have to stop somewhere, and scientists merely work on certain groups of facts so as to establish certain simple rules valid for those groups of facts only."

Among these definitions of science it may be well to remember *what science is not*. In my book *Economics of Khaddar* (Ganesan, Madras, 1928) I stated in regard to this,

"We sometimes forget that science and technique are not concerned primarily with size or appearance. There is as much science in studying the atom as in studying an ocean steamship. The watchmaker or spider have as fine a technique as the boilermaker or the bridge-builder. The smallness and relative simplicity of the charkha or the

slightness of power required for its use do not make it unscientific. Size and simplicity are only relative terms. . . . We must not confuse science with technology, nor with concentration of power. Science applies to all forms and degrees of power, and to all modes of technology."

Let us end these definitions of science with a quotation from Sir Oliver Lodge. It is found on page 1077 and following of Volume IV of J. A. Thomson's *Outline of Science* (G. P. Putnam's Sons, London, 1922):

"The direct aim of Science is Truth, and the temptation of its devotees is to concentrate too narrowly on this one aim, and to lose sight of the wealth of existence which gives all the meaning and value to bare fact; thus gaining but a purblind view of the universe, in spite of a large accumulation of knowledge which is accurate as far as it goes, but so incomplete as regards the totality of things as to be liable to mislead. . . .

"The particular aspect of the Universe which most impresses the man of science, at any one epoch, is liable to vary. Existence is so multifarious and bewildering in its scope and variety, that not only has humanity to make distinctions and contemplate things *seriatim*, but investigators must divide themselves into groups, and each group attend specially to its own department.

After mentioning the separate sciences of Biology, Physics, Chemistry and Physiology, he continues :

"These may be regarded as the major sciences, but there are many minor ones having to do with special portions of the Universe, like Geology and Geography and Meteorology, all related to the earth; others to do

with man, like History and Sociology and Anthropology and Archæology. And, of course, Biology has many branches, such as Physiology, the mode of working of the animal or vegetable organism, and Anatomy, its structure; also Zoology and Botany, dealing with the classification and habits of living things. Then, again, others have to do with practical applications, like Engineering and Medicine and Agriculture. The abstract science of number and form called Mathematics we have already referred to; and the separate branch of physics called Astronomy must be mentioned.

"Does then Science cover the whole of existence? By no means. There is the region of Art and Literature, and the whole realm of the good and the beautiful, which lie outside its scope: As human beings we have the right of entry; as men of science we must ask permission to enter. If we ignore all this realm, we suffer, and our philosophy is little better than dry bones—a skeleton which others may clothe with flesh and wake to life.

"The human spirit is more at home in Poetry and Literature and Art than it is in the groupings and cautious investigations of Science. . . . It is privileged to enjoy, and so far as may be to produce, beauty in music, in painting, in architecture, in poetry. And its achievements in these directions—Sonatas, Parthenons, and Divine Comedies—are of supreme interest to humanity, and rank among the highest creations of man. For in this region it is not discovery that is arrived at, but veritable creation—the production of some work of art that would not otherwise come into existence, and before which the man of science can only bow his head. Men like Shakespeare, Dante, Michael Angelo, Beethoven love and perceive the principles of Goodness, Truth and Beauty, all three, and have thus caught some glimpse of the Unchangeable Reality.

"There is no antagonism between poetry and science. There should be no antagonism between religion and scienc. There are many ways of arriving at Truth, the scientific path is but one.

". . . The mind of man is enriched from many divers channels; the feet of man are guided up the ascent by many divers paths. The aims are different, the good may be one. All roads lead to Rome, and all avenues conscientiously explored lead in the direction of the Truth. For the Truth is larger than what any man deems possible, and no one man or group of men has any monopoly over that divine fragrance."

Appendix A

Form and Arrangement of Written Work

[This was originally designed for a class using English, but most of it is also applicable to written work in any other language. Of course, in Urdu the margins would be placed at the right instead of at the left, and presumably other languages would have their own peculiarities, but the teacher can easily make whatever adaptations he may desire or find necessary.]

In every class in which written work is done, it is important to have the work clear, clean, neat, and so arranged that it is easy for the eye to discover the meaning, and see the progress and different parts of what the pupil is trying to express. In many instances the home surroundings of the pupils have not accustomed them to cleanness or good order. They are therefore unable to do clean, neat, clear, written work until they are shown what those words mean and how, in detail, such results can be obtained. It should be a part of the work of each teacher to give such training and then to insist on such work from the pupils.

Like all training, it must be done one step at a time, and with plenty of practice of each step. Merely telling the pupils to be neat is not enough. They have no standard to go by, and do not know how to attain a good standard even when it is shown to them. We must show them what real neatness is like, what are its elements, and how to do each part of the writing or drawing so as to make it all look neat.

Reasons for requiring Neatness

First of all we had better explain to them why orderly work is good. It is not merely because it is pretty or beautiful to look at, or because we teachers have fussy notions about writing, or because the school inspector likes to see work done in that way, or because it is the custom. No. We ask for cleanness and neatness in writing and drawing for the same reason that we expect every person to speak clearly and distinctly;—that is, so that other people will immediately and easily understand exactly what that person is trying to express, and without any mistake or confusion. Writing and drawing are ways of expressing ideas. Cleanness and neatness make it easy for the eye of the reader to understand those ideas and not to be confused or mistaken or delayed. Such ease gives pleasure to the reader, wholly apart from aesthetic appearances. Children talk plainly to each other. If they are going to write, they must write

plainly too. The appearance of a letter or any writing forms the first basis for judgment of the character of the writer, if he be unknown to the reader, just as the personal cleanliness, and clothing and general bearing and appearance of a man is the first basis for an impression or estimate of what he is like. It is of course only an imperfect and partial guide, but it does tell something. It is a part of one's communication with one's fellow beings. Then why neglect it? Therefore train the children to make their work look well. And let them know from the start that such writing means much more than merely well-formed letters.

Another reason for cleanness and neatness is connected with science. Science is concerned with the order and arrangement of things, events and matter in nature. Therefore any part of the pupil's training which instils a sense of order may be used to help him gain a broader understanding of science. Also the habit or orderliness requires care. Careful people are usually trusted and respected by others. If and in so far as the habit of care in school work tends to produce a general habit of carefulness in the pupil, the result will be of much value to him all his life.

Let us then take up the various steps which we want our pupils to follow and thus to acquire the ability and habits in this respect which we desire.

Do not use special printed record books, but have the boys make their own from bazaar paper, all of the same size and quality.

Spacing

When we examine any well printed text-book we realize that one of the things which helps us to understand it is the spacing of the printing. The spaces between words are wider than those between letters within a word. This separates, for the benefit of the eye, the meaning of each word from that of other words. The spaces between sentences are longer than those between individual words,—to indicate the separation of the thought of one sentence from another, and give the mind of the reader time to grasp the meaning of each sentence before the next begins. Likewise each paragraph is separated from the others by spaces still larger, because our minds need to pause longer to grasp the meaning of a whole paragraph before we travel on to the next big unit. Again still more space is allowed between the end of one chapter and the beginning of the next chapter; often the separation being increased by beginning a new chapter on a new page. In the same way, spaces are left in arithmetic books between different problems, and still greater spaces between different topics or subjects.

The blank margins around the edges of the printed matter on every page are another kind of spacing which helps the eye, and also helps to preserve the subject matter from dirt, loss by tearing etc.

Since, then, we know that these uses of spacing make every book more readily understandable, less tiring to the eye, more pleasant to read, and more useful, we may then point this all out in detail to our pupils and require them to do all their written work in like manner.

Teach them to make uniform spaces between all words, these spaces to be wider than those between the letters of the words themselves. Insist on this, and make them do it until it has become a fixed and unconscious habit with them. Crowding is especially apt to occur at the end of a line or at the bottom of a page. Do not permit it. If they crowd their work, make them write it again correctly. Have them leave longer spaces between sentences than between words. Require spaces between paragraphs to be wider than those between individual lines within a paragraph, though this last is not always essential. But it is necessary for them to 'indent' or begin each paragraph at least half an inch (preferably) a full inch further to the right than the beginning of the remaining lines of the paragraph. They should leave at least a

one inch margin on the left hand of each page, and a margin of $\frac{1}{2}$ to 1 inch on the right hand side, the top and the bottom. As the children are tempted to overrun the lines and write in the margin occasionally, you must insist, every time it occurs, that it is not allowed, and have them erase and do it again rightly. In arithmetic work, problems are to be separated from each other as if they were separate paragraphs in writing.

If they make any diagrams, drawings or maps to illustrate their writing, on the same page as the writing, they should of course leave at least half an inch margin all around the drawing to separate it from the writing. And even if the drawing is on a page by itself, it must be given as much margin as written work.

Whenever there is a wholly new story, composition, exercise, topic, or division of work started, it should be begun on a fresh page, even if the preceding page is only very slightly written upon. Paper is not very expensive. It is better apparently to waste a little space in order to get the pupils into the best habits in regard to neat work. The paper is not really wasted. The money invested in acquiring a good habit like this will yield ample interest in the course of time.

Titles and Headings

Properly written titles are a great help to the reader. To have them effective they should be made prominent either by their position on the page, by the large size of their letters, by greater blackness or heaviness of writing, by underscoring or underlining, by separation with extra space between them and the body of the text before and after. Inspection of titles, chapter headings or section headings in almost any book will make this clear to the children.

Generally it is best to place titles in the middle of the page; that is, half-way between right and left hand margins, and not running out toward either margin as far as the ends of the lines in the rest of the writing. Where titles are not printed but written, they should always be underlined in order to make them stand out boldly. With printed titles this is not always necessary because with printing it is fairly easy to make the letters larger and heavier than those in the text that follows. But even when titles are printed, in school-boy work, it is usually best for them to be underlined also. The underlining may consist of either one, two or three lines according to the importance of the title. For instance, a title for a whole note-book might have three underlines, a chapter title two underlines, a section heading only one underline.

Even though a title consists of many words, it should not be allowed to spread over the full width of the page, but be split up into as many lines as necessary, each line being underlined.

It is often customary for *section* headings to be placed on the left-hand side of the page, properly underlined and spaced off from what precedes and what follows. The space between the end of one section or chapter and the heading of the next section or chapter should be greater than the space between that heading and the section to which it belongs.

Where there are a number of minor sections or sub-sections as well as larger ones, it is customary to distinguish them by numbers and letters, thus :

“ Two important areas of India are divided as follows :

I. The Punjab, of which there are divisions such as,

A. Lahore

B. Simla Hills, including

1. Bushahr State

2. Kotkai State

3. Kumharsin State

4. Jubbal State

5. Kotgarh Ilāqa, comprising such villages as

(a) Kotgarh

(b) Pamālahi

- (c) Shatla
- (d) Dhada
- (e) Manksu
- (f) Barubag

II. Bombay presidency, including

A. Sindh

B. Gujarat, etc.

You will notice that each sub-division is indented (*i. e.*, given a wider margin) under its main or next preceding heading; also the numbers and letters to indicate each sub-head follow each other alternately, first a Roman number, then a capital letter, then an Arabic number, then a small letter. By this means the divisions are made clearer, especially if the writing has to be read aloud.

Titles of maps, plans or diagrams may be placed in the middle at the top or bottom, or in any of the corners, wherever they look best and have ample room. Additional information, such as scales, meaning of certain kinds of lines or signs, are usually placed in whichever corner there is most free space.

Clear, Uniform Letters and Figures

All letters and figures of a given kind should be written clearly, of uniform size and heaviness in any one section or line, and the style, form and shape of any one kind of letter or number should remain the same in that line

or section, except where a particular word, phrase or clause needs to be accentuated by using italics. Of course capital letters are of different size and sometimes different style from small letters, and Roman numbers are usually made of the same height as capital letters.

Slovenly, carelessly formed letters and figures should not be permitted. A figure four (4) must be written with the horizontal line cutting clear across the main vertical line, because if the horizontal line merely joins the vertical line there is likelihood, in fast writing, of the figure coming to look like a seven (7) or a nine (9), thus misleading the reader.

Printing

As a great aid to neat work it will be desirable for either the sixth or seventh standards to devote a certain amount of the science period, near the beginning of the year, to learning to print English letters and figures, and script letters.

To do this it will be necessary to have them draw light horizontal guide lines, the second line, say, one-quarter of an inch above the bottom line, and a third line one-eighth above that. These lines will permit big letters suitable for beginners. Later they may be given guide lines closer together, the distances apart to be the same as are found in the letters of some English book available to the

teacher. The round bodies of the English letters are to go between the two bottom lines and the tall upright parts of the letters run up to the top line. The teacher may rule similar guide lines, on a larger scale, on the blackboard and draw the letters of the alphabet, both small and capital, and a set of Arabic figures as models, and have the pupils copy them until they can do nice lettering by themselves. Begin with capital letters, then small letters, then Arabic figures, then Roman figures. Call attention to making the curved parts of the letters large and round, not thin and squeezed. Spacing between letters, words and sentences will need to be again emphasized. Note that the main vertical lines of the small letters are the same height as the capital letters. The small letters 'g' and 's' will be found especially difficult, and will therefore require more practice than others. In making the model letters on the blackboard the teacher may follow the style of type in any good standard English book, no matter what its subject.

Cleanness; Erasing

All work must be kept clean. For this reason pencils with very soft black lead cannot be allowed. Also the boys must wash their hands before coming to school or before this work. Smooches, smudges, blots and stains and finger marks must be cleaned away with an eraser,

If possible. Better still is not to have them occur at all. If a very large ink spot is made, it will be better to begin a fresh page. During all the work of learning how to print only pencils are to be used. After the boys have gained proficiency, they may use ink. When the eraser is used, it should be handed lightly, without heavy pressure on the paper,—blowing or lightly brushing off the little rolls of dirt that form under the eraser, instead of rubbing them away with heavy hand. Teach the boys to erase thoroughly and cleanly, so that it will not show afterwards. Covers and page margins must not be scribbled on, folded, blotted, dirtied or smooched.

Uniformity of Arrangement

Within any two sections or paragraphs or problems of the same nature or kind, the arrangement of divisions, parts, spacing, position, titles, etc., should be uniform. Such uniformity not only looks nice, but helps the reader quickly to understand what is presented.

Straight Lines and Columns

Do not allow pupils to write in lines that slant either up or down. It looks very badly. If they cannot write straight, let them first rule light horizontal guide lines at uniform distances apart.

In the same way care is needed to see that columns of figures are written in uniform

perpendicular lines. Decimal points must all come directly under one another; likewise figures with the same place value must be uniformly in perpendicular columns. To help in acquiring this habit at the start pupils may fold their paper in perpendicular creases like those in the Bania's account books.

Answers in Arithmetic

In all arithmetical work insist that the answers shall all be underscored and have the abbreviation "Ans." immediately following. Also if the answer is in some special concrete unit, other than a mere number, the name of the unit must be written as a part of the answer; thus :

526 sq. in. Ans., or $5\frac{5}{8}$ Ans., or Rs. 2-5-3 Ans.

Tables

When several measurements are made or five or six results obtained by the same method, it is often helpful to have the original figures and results arranged in the form of a neat table with carefully spaced and ruled columns and rows. In such cases all the lines of the table should be drawn before the titles or figures are written in. Have all lines squared and neat. The number of columns and rows should first be estimated and then drawn of the right width so as to come within the space available on the page and also be in a well balanced position. The width of each column and the height of

each row will depend partly on the number of figures to be written in it and partly on the number of words in its heading. Such words need not, however, be written all in a line, but may be divided into two or more lines. There should not be too much disproportion between the width of a column and the number of figures entered in each row within it. That is, do not have a column an inch and a half wide for a set of figures not over three digits each. Care should be taken to have the titles say what is really intended; that is, every figure in any one column or row must be exactly within the description given by the title of that column or row.

The appearance of tables is much neater if all titles in it are printed or in script letters rather than written. Every table should be given a name or title for itself as a whole; written either above or below it, preferably above.

Rough Work or Detailed Calculations

In arithmetic or science note-books all written figuring and calculation should be kept as a part of the record of each problem. In this way both teacher and pupil can check up the work quickly in case of error, and find out just where the mistake occurred. Do not allow such work to be done on 'scratch paper' or a slate and then be thrown away or erased. If a note-book is kept, it should be an original record

Write the word 'calculations' as a heading for that column, and do all the rough work inside that space. This will give a neat appearance to the page, provide sufficient space in almost all cases, and serve the whole purpose of the work. Of course, where problems require much calculation, the space provided may be made larger, $\frac{1}{2}$ or $\frac{2}{3}$ even of the width of the page instead of only $\frac{1}{3}$. Having such work always in the same place in reference to all the problems is a great help to any one who has to look over the work.

Inserted Records : Pasting

If plans, maps, or graphs have been made on separate sheets of paper, they may be pasted or glued into the note-book in the appropriate place. Such a sheet should have a name or title written or printed on it. If it is full page size, it may of course be simply inserted between two leaves with a little paste or mucilage along its left hand edge to stick it to the inner margin of the page. If it is larger than the page it may be folded, and then pasted in just the same way. If it is smaller than the page, it should be pasted on the page at even distances from both margins, either at the beginning of the section or problem to which it belongs or in the middle of it.

When preparing to paste such a sheet, do not put the paste or mucilage over all the back of the paper to be inserted. Put a little paste

at each of its four corners, or one line or strip of paste along the back of that edge of it which will be nearest to the binding of the note-book. The latter way is perhaps preferable. Do not put on too much paste, or allow it to be smooched on to other parts of the page. If there is excess paste, and it squeezes out from under the paper, wipe it off with a bit of clean cloth, and dry the place with blotting paper, so that the pages will not stick together.

Sketches or Diagrams

These should be treated somewhat like tables, being put in a suitable position on the page, having a title given them, and adequate margins left all around them to separate them from the text.

Signatures and Dates

Each piece of written work should bear a date either of the day when it was begun, or when it was finished or handed to the teacher. It is of course in the discretion of the teacher which of these dates to choose, and it may differ with different kinds of work, but the method of dating similar pieces of work should be uniform.

Where compositions, essays, stories, problems, pictures, sketches, plans, maps, or other written work are handed in on separate sheets of paper, each sheet should bear the pupil's signature, and the work of that day should bear the date also.

If the work is in a note-book, the book should bear on the fly-leaf or inner cover the pupil's signature, the number of his Standard or Class, the subject and date of commencement of the note-book, as well as have each separate piece of work in it dated for itself. Have all dates written uniformly and in full, thus, January 27, 1928.

The matter of signatures is important for identification, and to give the pupil a sense of responsibility for everything that he writes. Dates also help in identification. For purposes of rapid identification of note-books, the pupil's name may be printed on the outside as well as written inside. It is suggested, that the name inside should be written rather than printed, in order that the peculiar characteristic of each pupil's written signature may become familiar to the teacher, as further identification.

Suggestions, not rigid Rules

The foregoing are not rigid rules to be slavishly followed. They are suggestions growing out of long experience and observation, and will be found generally applicable, useful and tending to produce good looking and easy reading manuscript. Yet some are matters of taste and hence open to change; others will not apply in special instances or circumstances. They are merely offered for whatever they may be worth.

Appendix B

Material and Apparatus Suggested for The Foregoing Exercises in Arrangement

(Estimate for a class of ten boys)

(Probable maximum cost, exclusive of watch, Rs. 45; and this may be much reduced by appropriate substitutions of various articles and by having others made by village artisans. Of course not all of the material is necessary at the start, either.)

Large buttons, black, grey, white, red, about 100 of each colour.

Small buttons, same colours, 100 of each.

Soap nuts (*aritha*), perhaps 400.

Marbles, three kinds or colours, about 100 of each.

Fairly stiff paper, foolscap size, any colour, 300 sheets.

Large glass beads, such as are used on the harness of mules and oxen, blue, white, red and black, 100 of each.

Tinned or galvanised sheet iron, perhaps from an old oil cannister, to be cut into small squares and discs.

Copper wire, about $1/16$ to $1/8$ of an inch diameter, about 30 feet.

Iron wire, about $1/32$ of an inch diameter, about 40 feet.

Coloured crayons, perhaps six colours and five of each

colour.

Ten large corks.

Ten cheap thimbles.

Two cheap rubber balls.

One cheap wood or tin fife or flute.

Bits of different coloured yarn, about 100.

Bits of different coloured cloth, not over 3 sq. in. each, say 100.

Twenty large sheets of squared ruled paper, ruled to inches and tenths of an inch.

Five large sheets of pasteboard or heavy cardboard.

One ball of strong string.

Two packs of playing cards.

Two hundred cubes of wood or sun-baked clay, one inch on a side.

One hundred sheets of plain unruled white paper, foolscap size.

Two cheap balance scales such as are used in bazaars, with two sets of tola weights.

Two sets of ounce weights.

Two cheap sets of water colour paints and ten cheap brushes.

Fifteen medium soft lead pencils.

Fifteen medium hard lead pencils.

One convex lens.

One Fahrenheit thermometer, if possible reading to 220 degrees above zero.

Ten glass tumblers, heavy.

One metre measuring stick.

Five foot rules graduated in inches and down to eighths of an inch.

Five or ten cheap sets of drawing instruments—protractor, compasses, one 45 degrees set-square, one 60 and 30 degrees set-square, short rule graduated in inches and

tenths of an inch, same graduated in centimetres and millimetres.

Ten 4 oz. bottles with wide mouths.

One large glass jar with wide mouth.

One watch (may use any one that is available). A clock with a second hand will do.

About twelve wooden boards or trays, perhaps $1\frac{1}{2}$ square feet in area, or shallow baskets of same size.

Not all these are absolutely necessary, and by sharing, a smaller quantity of each will serve. Substitutes for many of them may be worked out. If some of them cannot be obtained, and no substitute is available (*e.g.*, convex lens), the exercise requiring it may of course be omitted.

Appendix C

Books on Science *for* Village Teachers

For his own interest and enlargement of mind, and also as a source of suggestions in teaching the foregoing exercises and any possible subsequent teaching of elementary science, the teacher will probably want to do some reading. As I have no means of learning what is available for this purpose in the various vernaculars, I can merely suggest a number of books in English. Since the village teacher's purse is necessarily limited, I have listed only inexpensive books and also given their prices. But despite their low cost they are all thoroughly good. Furthermore, inasmuch as many teachers in remote villages may not know the names of any bookshops through which English text-books may be purchased, I suggest the following, without prejudice as to the many others which are probably just as good. But with these I have myself dealt and can recommend them:— D. B. Taraporevala Sons & Co., Hornby Road, Bombay; R. Cambray & Co., College Square, Calcutta; or Tagore & Co., 145 Mint St., G. T., Madras.

Books giving Courses of Experiments

Easy Experiments in Elementary Science, by Herbert McKay, Oxford University Press, London, 1923.

About 1s. 6d. Very simple cheap apparatus.

Individual Work in Science, by Herbert McKay, Oxford University Press, London. Parts I, II and III, each 1s. 3d. Part IV, Teacher's Book, 3s. 6d.

A Graduated Course of Natural Science, by Benjamin Loewy, Macmillan, London, 1912. Part I, 2s., Part II, 2s. 6d.

Books describing Different Sciences

Published by Isaac Pitman & Sons, London:

Mastery of Air—3s.

Mastery of Earth—3s.

Mastery of Fire—3s.

Mastery of Water—3s.

Nature's Mystic Movements—Heat, Light, Sound,
by A. T. McDougal, 2s. 6d.

Nature's Giant Forces—Properties of Matter,
Vol. I, by A. T. McDougal, 2s.

Nature's Wondrous Laws—Properties of Matter,
Vol. II, 2s.

Triumph of Man—3s.

Wonders of Electricity—2s. 6d.

Published by G. Bell & Sons, London:

Readable School Mechanics—R. C. Fawdry—2s. 4d.

Readable School Physics—J. A. Cochrane—2s. 4d.

Readable School Chemistry—J. A. Cochrane—2s.

Published by Macmillan & Co., London:

Wonders of Physical Science—by E. E. Fournier
1s. 9d.

Achievements of Chemical Science—by J. C. Phillip,
2s. 6d.

Tillers of the Ground—by M. I. Newbigin, 2s. 6d.

The Changeful Earth—by G. A. J. Cole, 2s. 6d.

Home University Library Series, published by Williams
and Norgate, London, one shilling each:

Introduction to Science, by J. A. Thomson

Matter and Energy, by F. Soddy

Principles of Physiology, by J. G. McKendrick

The Human Body, by A. Keith

Health and Disease, by W. L. Mackenzie

Plant Life, by J. B. Farmer

Evolution of Plants, by D. H. Scott

The Animal World, by F. W. Gamble

The Making of the Earth, by J. W. Gregory

Evolution, by J. A. Thomson and P. Geddes

The Mineral world, by T. W. Holland

Climate and Weather, by H. N. Dickson

Astronomy by A. R. Hinks

Electricity, by G. Kapp

Chemistry, by R. Meldola

Psychology, by W. McDougal

Anthropology, by R. R. Marrett

The People's Books Series, published by T. Nelson & Sons,
London, one shilling each:

The Foundations of Science

Science of Light

Weather Science

Evolution

Embryology

Biology

Zoology

Botany

Bacteriology

Heredity

Inorganic Chemistry

1473

Organic Chemistry
 Radiation
 Principles of Electricity
 Science of Stars
 Practical Astronomy
 Navigation
 Aviation
 Applications of Electricity for Non-Technical Readers
 Pond Life

Everyman's Library Series, published by J. M. Dent & Sons, London, 2s. each. The number of each book in the series is also given:

| | |
|--|-------|
| Man's Place in Nature, by T. Huxley | (47) |
| Glaciers of the Alps, by Tyndall | (98) |
| Inquiries into Human Faculty, by F. Galton | (263) |
| Naturalist on the Amazon, by Bates | (446) |
| Select Lectures and Lay Sermons, by T. Huxley | (493) |
| Experimental Researches in Electricity, by Faraday | (576) |
| Advancement of Learning, by Bacon | (719) |

House Flies and How they spread Disease, by C. G. Hewett. Cambridge Manuals of Science and Literature 2s. 6d. Cambridge University Press, 1912.

Judging Dairy Cattle, by G. C. Humphrey, Bulletin 335, 2nd edition revised, 1913, University of Wisconsin, Madison, Wis., U. S. A. About 5 cents.

The Cow, the Mother of Prosperity, by Ralph A. Hayne, Agricultural Extension Dept., International Harvester Co., Inc., Chicago, Illinois, U. S. A. About 5 cents).

There are many other books on elementary science just as good and just as cheap in price as these. Booksellers and publishers will be glad to give information about them. This list does not profess to be complete or to be only of

the very best. It merely offers some good inexpensive books from which a teacher may choose to suit his own interests and needs. Later he may widen his choice to suit himself. I regret that I am unable to mention any books by Indian authors, but it is very difficult for me in this remote corner in the Himalayas to learn the names and addresses of Indian publishers of books on science. The booksellers above named can perhaps supply the omission, but pressure of work does not permit me to do this now.

THE END

